THE UNIVERSITY OF ALBERTA

A MANUFACTURING RESOURCE PLANNING SYSTEM

By

BENG F. LIM ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF MECHANICAL ENGINEERING

EDMONTON, ALBERTA

SPRING, 1999

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "A MANUFACTURING RESOURCE PLANNING SYSTEM" submitted by BENG F. LIM in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

....JC Sprague.......
J.C. Sprague
Supervisor

....B.M. Patchett.....
B.M. Patchett

....Franz Vitovec.....
F.H. Vitovec

Date.....October 4th 1982.........

ABSTRACT

The task involved in this thesis is concerned with designing some of the major elements (Forecasting, Master Production Schedule, Resource Requirements Planning and Capacity Requirements Planning sub-systems) of the Manufacturing Resource Planning system applicable to Argo Engineering Limited.

Basically, a Manufacturing Resource Planning system is a closed loop computerized production-inventory planning and control system. The work on the balance of the major sub-systems are undertaken by E.S. Kombe and D. Quek. E.S. Kombe is designing the major elements of Inventory Planning, Identification System (Bill of Materials) and Production Scheduling.

Each of the above mentioned major sub-systems undertaken in this thesis involved a substantial amount of computer programming. The computer programs are extensively documented.

It is anticipated that with minor modifications, the system may be implemented in other industrial plants.

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation for the inspiration, guidance and supervision rendered by Dr. J.C. Sprague in the preparation of this thesis.

The author is much obliged to Mr. Loblick for his time and assistance during the visits to Argo Engineering Limited.

Thanks to Miss Kean Goh for typing this thesis.

Last but not least, the author is grateful to his parents for their encouragement.

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1. INTRODUCTION

1.1 Purpose

The purpose of this thesis is to design some of the major sub-systems of a Manufacturing Resource Planning system; namely the Master Production Schedule, the Resource Requirements (or Rough-Cut Capacity) Planning Simulation Model, the Capacity Requirements Planning Simulation Model and the Forecasting Model applicable to Argo Engineering Limited.

It is envisaged that with minor modifications, the system may be installed in other industrial plants.

1.2 Background Information

Argo Engineering Limited manufactures and markets materials handling equipment. Among the range of materials handling equipment are dock levellers, elevating docks, hand trucks, platform lifts, wheelchairs or handicapped lifts and shelving and racking equipment. Dock levellers, and elevating docks account for approximately 60% of the total dollar sales volume.

The company is based in Edmonton with a subsidiary manufacturing plant in Ajax, Ontario. The company also has manufacturing licensing arrangements with several companies around the world.

1.3 Problem Statement

At present, the company practices an informal form of production-inventory planning and control system. The method is based on a combination of experience, 'trial and error' and a reorder point system.

Although the existing manual system works reasonably well, the company is interested in further improving the performance of its production-inventory control and planning system. This interest and perhaps a need is necessary for an improved system in order to cope with rampant inflation, rapidly rising labour and material costs, high interest rates and increasing competition.

One effective answer to the problem is to design and implement a fully integrated Manufacturing Resource Planning system.

1.4 Overview of Manufacturing Resource Planning

The schematic layout of Manufacturing Resource Planning (referred to as MRP II by the American Production and Inventory Control Society) is depicted in Figure 1.1.

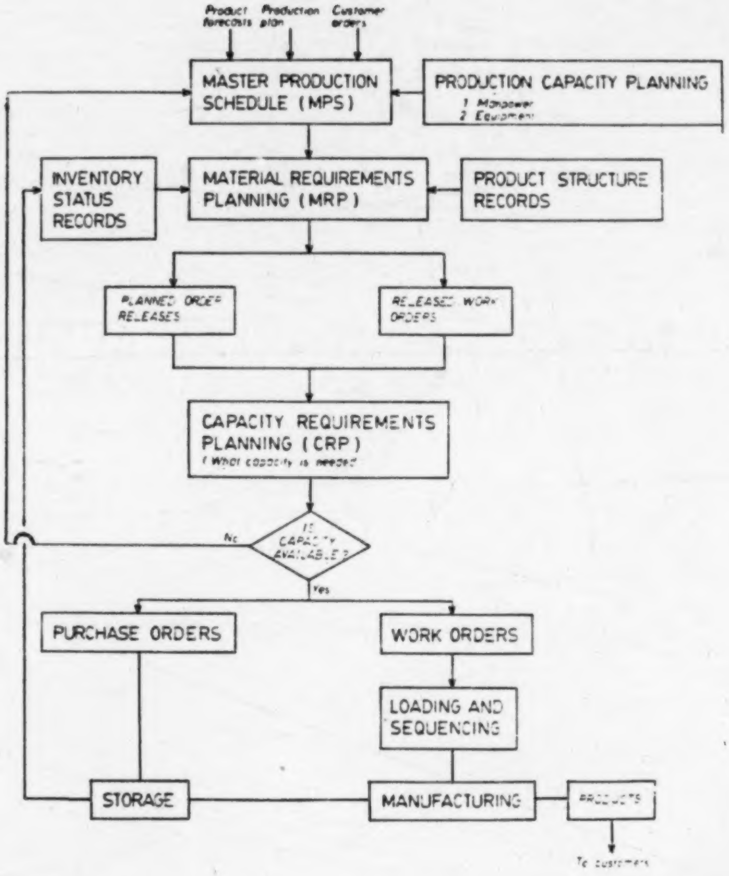


Figure 1.1 Manufacturing Resource Planning Process

The Forecasting sub-system is only used to determine the requirements of independent demand items. Dependent demand items need not be forecasted, but are calculated by the Material Requirements Planning sub-system from the Master Production Schedule.

The sales forecast must be uncoupled from the Material Requirements Planning sub-system. The sales forecast has a tendency to fluctuate. The production work load should be smoothed in order to have an efficient running plant. This is achieved by Master Production Scheduling. The Master Production Schedule is needed to control the fluctuations the demand can place on the factory. In fact, the backbone of a Manufacturing Resource Planning system is the Master Production Schedule. The Short Term Master Production Schedule "drives" the Manufacturing Resource Planning system by establishing the demand. The Master Production Schedule must be a realistic and realizable schedule. To insure capacity availability at a gross level, an initial check is made on the Long Term Master Production Schedule.

Resource Requirements Planning or long range capacity planning is the technique employed to check on the Long Term Master Production Schedule. In either an underload or overload case, appropriate action is taken to resolve the situation. The Long Term Master Production Schedule is revised until an acceptable schedule is agreed upon by production planning and control, manufacturing, marketing and finance.

The Bill of Materials (BOM) record, contains information on every item or assembly required to produce end items. Information on each item, such as part numbers, description, quantity per assembly, next higher assembly and quantity per end item are also available. It is vital that the information contained in the Bill of Materials be accurate. The success of a Manufacturing Resource Planning system depends on the integrity of the input information.

The Inventory Status Records contain the status of all items in inventory. All inventory items must be uniquely identified. These records must be kept up to date with each receipt, disbursement or withdrawal documented to maintain record integrity. They should also contain information on lead time, lot sizes or other item peculiarities.

These three sources (Master Production Schedule, Bill of Materials and Inventory Status Records) are the data inputs for the Material Requirements Planning sub-system.

The Material Requirements Planning sub-system takes the Short Term Master Production Schedule for end items and determines the gross quantities of components required by exploding the end item Bill of Materials into its lower level requirements. The exploding process is simply a multiplication of the number of end items by the quantity of each component required to produce a single end item. The explosion identifies what components are required, as well as how many to produce a given quantity of end items. By referring to the inventory status records, the gross quantities will be netted by subtracting the available inventory items. Just as important as "*what*" and "*how many*" is "*when*", which is determined by offsetting (setting back in time) the lead times for each component. Thus, the material requirements for each component are phased over time in a pattern determined by lead times and parent requirements.

The output of the Material Requirements Planning sub-system indicates what component items will have to be produced and when. This output is converted into the capacities required to produce these items. Capacity Requirements Planning is used to achieve this purpose. Through Capacity Requirements Planning, it is possible to determine what capacities by work center by period, in the short-to-medium range, are required to meet production goals.

1.5 Scope and Methodology

The entire project is to develop the major elements of the Manufacturing Resource Planning system. The major sub-systems covered by the entire project are listed as follows:

- Forecasting,
- Master Production Schedule,
- Resource Requirements Planning,
- Material Requirements Planning,

- Bill of Materials,
- Inventory Planning and Control, and
- Capacity Requirements Planning.

This thesis concentrates on the key functional components of:

- Forecasting,
- Master Production Schedule (MPS),
- Resource Requirements Planning (RRP), and
- Capacity Requirements Planning (CRP).

Computer models are developed for each of the sub-systems. These modular software packages are specifically designed to be used on the IBM personal computer.

Forecasting

The Exponential Weighted Moving Average Model was selected and developed as a computer program. The program designed has the capability of being able to select the appropriate sub-model to forecast situations where either "random", "trend", or "seasonal" patterns prevail. In other words, the forecasting program is adaptive in nature. The forecasts are derived by projecting and smoothing the actual demand pattern.

Master Production Schedule

The work in this area involved the development of a simulation program. A realistic and realizable Master Production Schedule is developed by running sets of raw schedules on a trial basis. The Master Production Schedule program makes the necessary calculations to yield the trial Long and Short Term Master Production Schedules. The trial Long Term Master Production Schedules are simulated through the Resource Requirements Planning program to check for capacity availability. In addition, the Master Production Schedule Model generates two other reports, namely:

1. End Item File, and
2. Receipt List.

The trial Short Term Master Production Schedules are used to "drive" the Materials Requirements Planning sub-system.

Resource Requirements Planning

The resource requirements planning objective is achieved by developing a simulation program. The program processes the trial Long Term Master Production Schedules and outputs the resource requirements for each trial Long Term Master Production Schedule. The reports also highlight whether resources have been under or over-utilized. The reports generated are:

1. Long Term Work Center Report, and
2. Overload Report.

Capacity Requirements Planning

Similarly, this area involved the development of a simulation program. The program outputs the following reports which accommodate various purposes:

1. Work Centre Load Report,
2. Overload Report, and

3. Component Part Scheduling Report.

These reports may be used by management to plan and control shop floor scheduling in the most efficient manner.

The remaining major sub-systems of the Manufacturing Resource Planning system are covered by the thesis of E.S. Kombe and the engineering report of D.Quek. E.S. Kombe is undertaking the task of designing an identification system which is used for structuring the Bill of Materials in the future. In the process of setting up the Bill of Materials, the thesis involves the development of an inventory planning and control system. It extends to investigating the production scheduling problem in an attempt to devise scheduling rules and guidelines.

D. Quek is developing the Material Requirements Planning program for the Manufacturing Resource Planning system.

The computer programs are written in Fortran using the IBM personal computer.

Figure 1.2 shows the project division of the entire Manufacturing Resource Planning system.

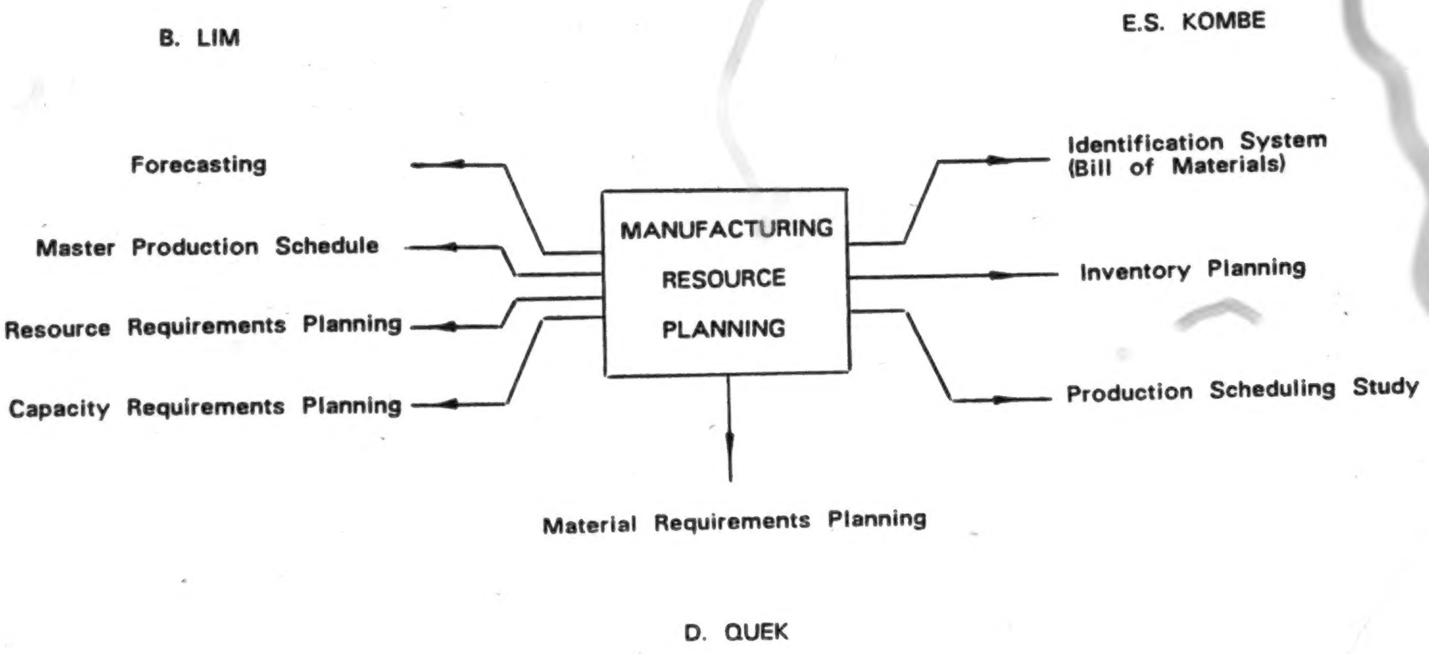

B. LIM
E.S. KOMBE
Forecasting
Master Production Schedule
Resource Requirements Planning
Capacity Requirements Planning
MANUFACTURING RESOURCE PLANNING
Identification System (Bill of Materials)
Inventory Planning
Production Scheduling Study
Material Requirements Planning
D. QUEK

Figure 1.2 Manufacturing Resource Planning System Project Division

2. INDEPENDENT DEMAND FORECASTS

2.1 Forecasting

Planning and control for production-inventory systems must neccessarily take place at several different levels. Therefore, it is unlikely that one kind of forecast can do the job. To be sure, the immediate problem is always the controlling of inventories, providing raw materials for current production programs, planning the use of workers and machines on a day-to-day basis, week-to-week, or month-to-month basis. However, it is important to look somewhat farther into the future to provide for new capacity or a different kind of capacity. The result is that forecasts are required for different time spans:

1. plans for current operations and for the immediate future;
2. intermediate range plans to provide for the required capacities of workers, materials and equipment for the next one to two years; and
3. long range plans for plant and warehouse capacity, plant location, changing product mix and the exploitation of new products.

To cater for each individual requirement, forecasts are made at three different levels; namely:

1. short term forecasting,
2. intermediate term forecasting, and

3. long term forecasting.

J.A.Orlicky proposed the Dependent and Independent Demand Principle in which he stated that:

> *"When items are independent such as finished goods, items or service parts not used in current production, where the demand of certain items is unrelated to the demand of other items, it is necessary to forecast demand. In turn, where the demand is dependent, related to the demand for other items, it has to be calculated through the Bill of Materials explosion based on the demand for the finished good items [24]."*

Several forecasting techniques are available for forecasting independent demand items.

There are three broad classifications of forecasting techniques:

1. qualitative techniques,
2. time series analysis and projection, and
3. causal models.

The first uses qualitative data (expert opinion for example) and information about special events of the kind already mentioned and may or may not take the past into consideration. The second, on the other hand, focuses entirely on patterns and pattern changes and thus relies entirely on historical data. The third uses highly refined and specific information about relationships between system elements and is powerful enough to take special events formally into account. As with time series analysis and projection techniques, the past is unimportant to causal models.

Time series analysis include a wide variety of techniques with varying degrees of sophistication, ranging from the very simple weighted average technique to adaptive forecasting. The Exponential Weighted Moving Average (EWMA) technique was selected for the following reasons :

1. The only input data required is historical data. Such data is readily available at Argo Engineering Limited. There is no need to incur a substantial amount of expense in preparing and collecting the necessary input information.
2. A person can make use of the model with a minimum amount of training and supervision.
3. The model is capable of producing fairly accurate forecasts in the short and intermediate term.

2.2 Determination of Forecasted Demand

The forecasted demand is derived by following a set of procedures. These procedures are intended to produce forecasts of acceptable accuracy. The responsibility of forecasting is defined as part of the function of sales and marketing. Sales and marketing usually assign the job of running the Forecasting Model to the marketing analyst. A typical forecasting procedure is described in a step-by-step manner below:

1. In the first instance, the marketing analyst produces a long term forecast by running historical sales data

through the Forecasting Model. The historical sales data is in the form of semi-annual sales for the past six years. The Forecasting Model makes semi-annual projections for the next six years. The marketing analyst then inputs monthly sales for the past year into the Forecasting Model to generate the Short Term Forecast Report.

2. The marketing analyst comments upon the forecast outputs. Copies are then distributed to the senior managers of the respective departments. The senior manager of sales and marketing then organizes a meeting to discuss the forecast reports.
3. The senior managers each express their opinions regarding the forecasts. Following discussion and by consensus of opinion, the forecasts are adjusted to take into account the experience and expertise of the various managers. This is an important factor because the forecasts produced by the Forecasting Model do not incorporate sociological, psychological and economical factors in the computation. Adjustments may be necessary to account for these factors.
4. The finalized long and short term forecasts are passed to the Master Scheduler to serve as input into the Master Production Schedule Model.

2.3 The Forecasting Computer Program

The model design is based on the following rules:

1. The most recent data is allocated the heaviest weighting and vice-versa for the oldest data. The exact weighting allocated depends on the value of the smoothing constant. The higher the value of the smoothing constant, the heavier the weighting is allocated to the most recent data and vice-versa.
2. The total mean absolute deviation is the sole criterion for deciding which is the best sub-model (AVG or TREND or SEASON) to be used for forecasting.
3. The best smoothing constant is determined internally by the Forecasting Model. The total mean standard error and the total mean absolute deviation are the criteria used for determining the best smoothing constant.
4. The model generates forecasts for twelve periods by utilizing twelve historical demand data points. The latter consists of data immediately preceding the periods to be forecasted. For example, to forecast for the twelve months of 1983, twelve monthly historical demand data points for the year 1982 are utilized as input data.
5. Fourteen base series demand data points are also required as input data. With reference to the above example the base series demand data will consist of fourteen data points selected from the twelve months of 1982 and the last two months of 1981.

The first base series is derived by adding the first three historical data points and dividing the result by three. The second base series is arrived at by adding the second, third and fourth data points and dividing the result by three. The fourteen historical data points thus yield twelve base series data points. Each of the twelve historical demand data points is divided by the corresponding base series data points and the results are subsequently utilized for forecasting.

2.3.1 Model Algorithm

The algorithmic flow of the Exponential Weighted Moving Average Model is depicted in Figure 2.1.

The variables used in the flow diagram are defined in Appendix A.

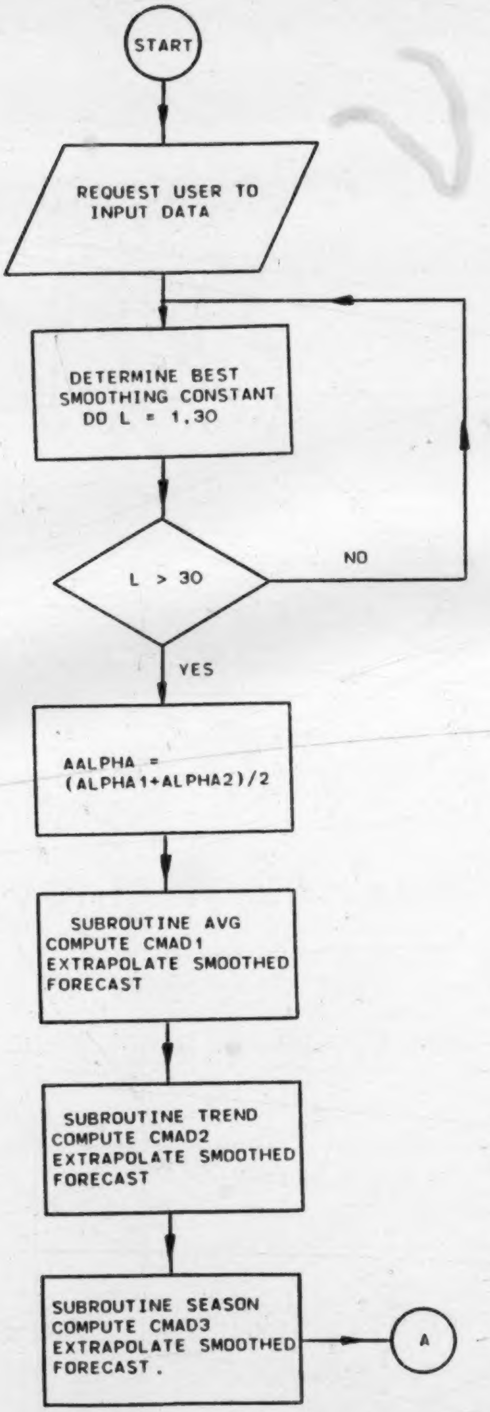

START
REQUEST USER TO INPUT DATA
DETERMINE BEST SMOOTHING CONSTANT DO L = 1,30
L > 30
NO
YES
AALPHA = (ALPHA1+ALPHA2)/2
SUBROUTINE AVG COMPUTE CMAD1 EXTRAPOLATE SMOOTHED FORECAST
SUBROUTINE TREND COMPUTE CMAD2 EXTRAPOLATE SMOOTHED FORECAST
SUBROUTINE SEASON COMPUTE CMAD3 EXTRAPOLATE SMOOTHED FORECAST.
A

Figure 2.1 Forecasting Model Flow Chart

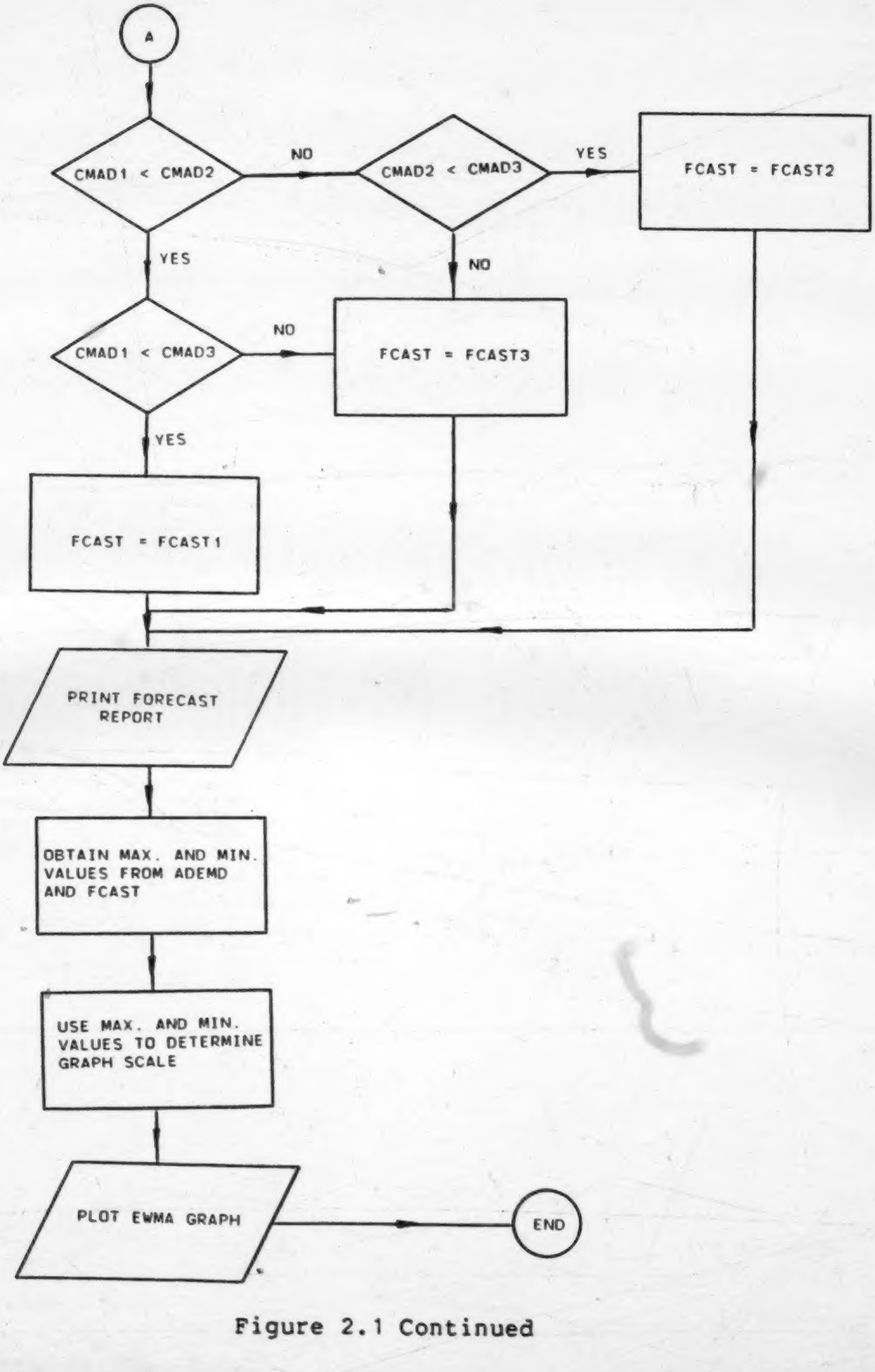


Figure 2.1 Continued

The description of the algorithmic flow is summarized as follows:

1. The main program reads the historical sales and base series demand data.
2. The main program passes the input data to the AVG, TREND and SEASON subroutines. The subroutines compute the total mean absolute deviation individually. The main program selects the subroutine with the smallest total mean absolute deviation.
3. In addition to determining the total mean absolute deviation, the subroutine also computes the smoothed forecasted demand using the best smoothing constant.
4. The smoothed forecasted demand associated with the smallest total mean absolute deviation is passed to the main program. The main program transfers the results to the report and plot subroutines.
5. The results are printed on the line printer by the command of the report and plot subroutines.

2.4 Testing the Model

This model accepts any type of data irrespective of its source. The data tested are hypothetical because it is intended to show the dynamics and versatility of the model.

To run the model, the user is only required to load the executable file into the core memory by typing in the file name **FM** . The model is brought into conversational mode and all the user has to do is to key in the data requested.

2.4.1 Interactive Input Data Format

The displays on the visual display unit are as follows:

```
*********************
* FORECASTING MODEL *
*********************

Enter today's date (mm/dd/yy):
08/20/82
Enter forecast item (40 alpha-characters):
Dock Leveller Model M68
Enter forecast for month or year (semi-annual):
Press 1 for month
Press 2 for year (semi-annual)
2
Enter forecast period:
(Example: 1982 to 1987)
(40 alpha-characters)
1982 to 1987
Enter 14 historical data points in units for base series
demand on a single line (XXXXX.X real each):
00130.0 00128.0 00130.0 00125.0 00127.0 00132.0 00133.0
00130.0 00126.0 00128.0 00125.0 00129.0 00123.0 00128.0
Enter 12 historical data points in units for past historical
demand on a single line (XXXXX.X real each):
```

```
00130.0 00125.0 00127.0 00132.0 00133.0 00130.0 00126.0
00128.0 00125.0 00129.0 00123.0 00128.0
```

Once the user presses ENTER following the last entry of 00128.0, the next display is:

```
**** PROCESSING .......
```

2.4.2 Output Data Format

The output data is printed on the line printer. It consists of a Long Term Forecast Tabular Report and a Long Term Forecast Graphical Report. The results are shown in Tables 2.1 and 2.2.

On the other hand, the user may key in "1" following the prompt:

```
Enter forecast for month or year (semi-annual):
Press 1 for month
Press 2 for year (semi-annual)
1
```

The next few prompts which follow are listed below:

```
Enter forecast period:
(Example: Jan 1982 to Dec 1982)
(40 alpha-character)
Aug 1982 to July 1983
Enter 14 historical data points in units for base series
demand on a single line (XXXXX.X real each):
00020.0 00021.0 00020.0 00022.0 00021.0 00020.0 00021.0
00022.0 00020.0 00020.0 00022.0 00021.0 00020.0 00021.0
Enter 12 historical data points in units for past historical
```

demand on a single line (XXXXX.X real each):

00021.0 00020.0 00020.0 00021.0 00020.0 00021.0 00022.0 00020.0 00021.0 00021.0 00022.0 00020.0

The visual display unit will indicate to the user that the central processing unit is in progress by displaying:

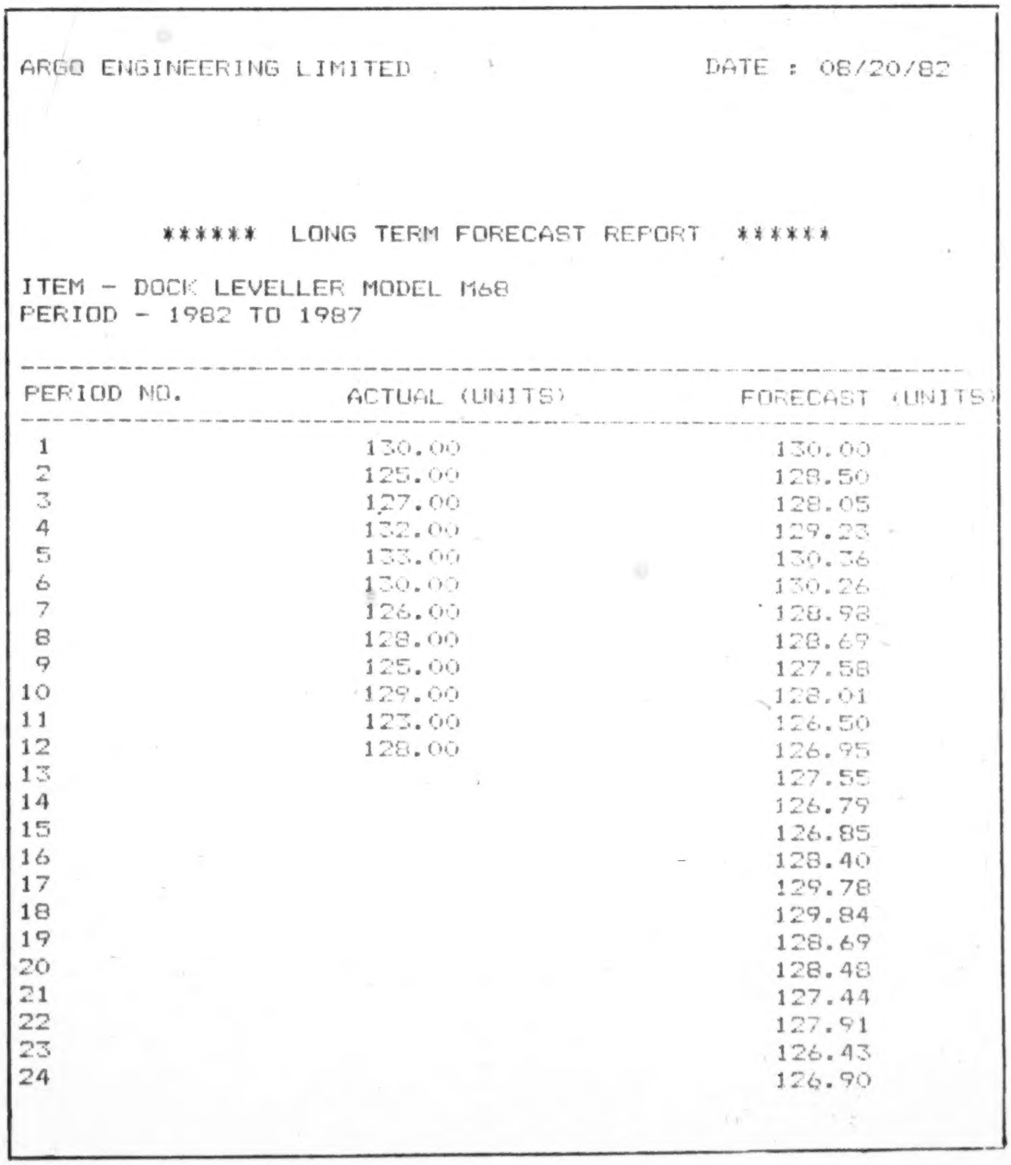
****** PROCESSING ......**

In this case, the output data will be a Short Term Forecast Tabular Report and a Short Term Forecast Graphical Report. The results are depicted in Tables 2.3 and 2.4.

The Forecasting Model is tested with the product, Dock Leveller Model M610 for the purpose of comparison with the previous two examples and showing the effectiveness of the model. The results are shown in Tables 2.5, 2.6, 2.7 and 2.8.

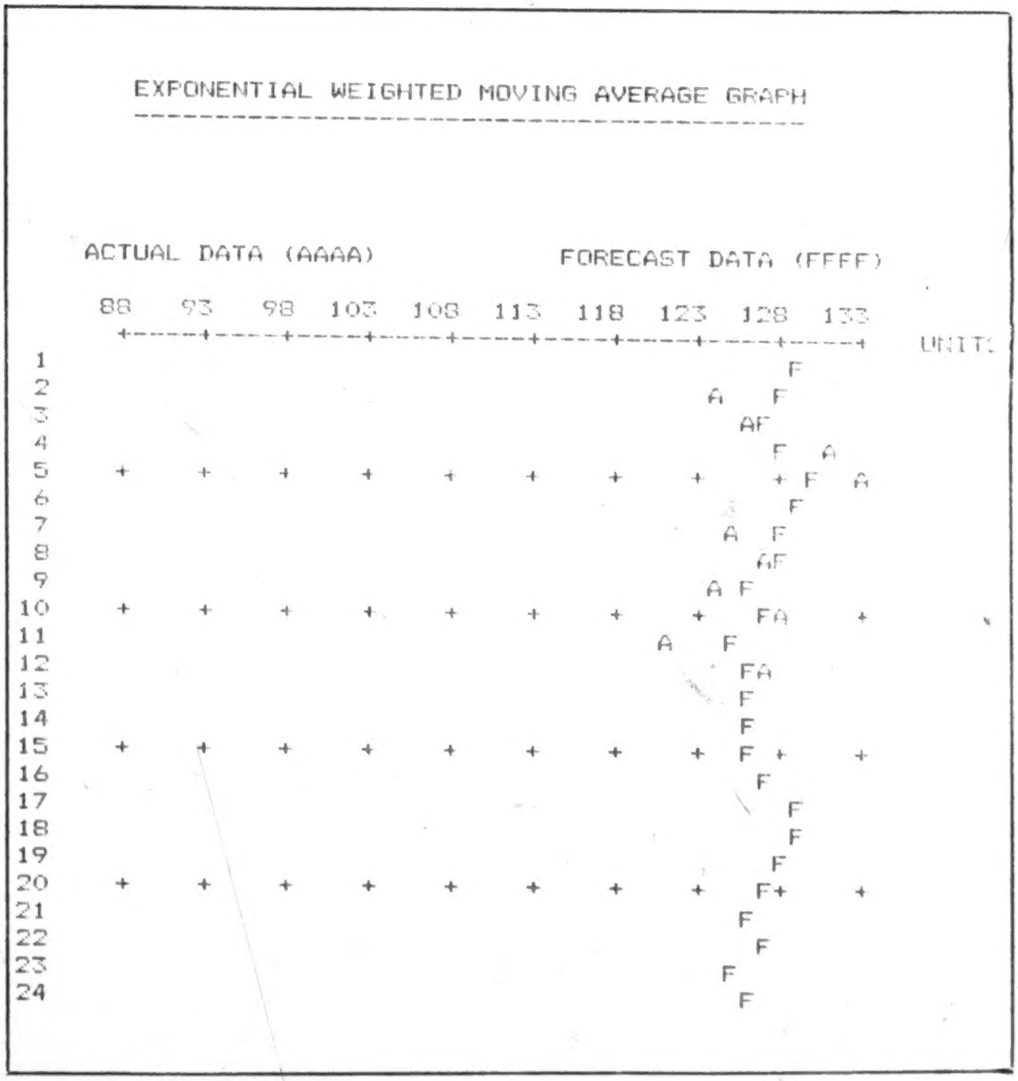
The graphical report complements the numerical results by displaying the latter graphically so that the pattern of demand is shown more clearly.

Table 2.1 DLM68 Long Term Forecast Report



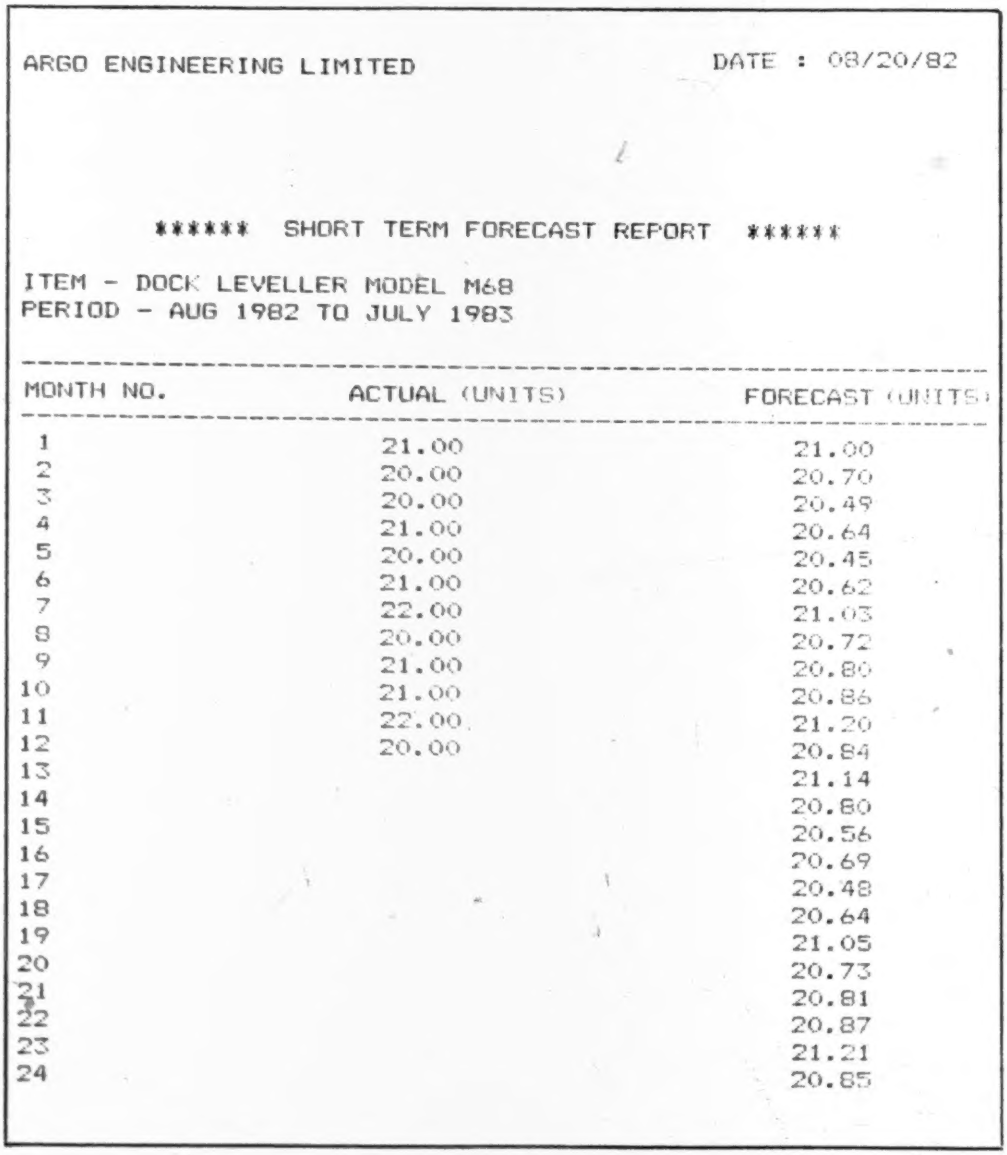
```
ARGO ENGINEERING LIMITED                    DATE : 08/20/82



         ******  LONG TERM FORECAST REPORT   ******

ITEM - DOCK LEVELLER MODEL M68
PERIOD - 1982 TO 1987

--------------------------------------------------------------
PERIOD NO.          ACTUAL (UNITS)          FORECAST (UNITS)
--------------------------------------------------------------
 1                    130.00                  130.00
 2                    125.00                  128.50
 3                    127.00                  128.05
 4                    132.00                  129.23
 5                    133.00                  130.36
 6                    130.00                  130.26
 7                    126.00                  128.98
 8                    128.00                  128.69
 9                    125.00                  127.58
10                    129.00                  128.01
11                    123.00                  126.50
12                    128.00                  126.95
13                                            127.55
14                                            126.79
15                                            126.85
16                                            128.40
17                                            129.78
18                                            129.84
19                                            128.69
20                                            128.48
21                                            127.44
22                                            127.91
23                                            126.43
24                                            126.90
```

Table 2.2 DLM68 Long Term Forecast Graph



```
       EXPONENTIAL WEIGHTED MOVING AVERAGE GRAPH
       -----------------------------------------



    ACTUAL DATA (AAAA)           FORECAST DATA (FFFF)

     88   93   98  103  108  113  118  123  128  133
      +----+----+----+----+----+----+----+----+----+----+   UNITS
 1                                             F
 2                                        A   F
 3                                          AF
 4                                            F  A
 5    +    +    +    +    +    +    +    +    + F  A
 6                                             F
 7                                         A  F
 8                                           AF
 9                                        A F
10    +    +    +    +    +    +    +    +   FA    +
11                                     A   F
12                                          FA
13                                          F
14                                          F
15    +    +    +    +    +    +    +    +  F +    +
16                                           F
17                                             F
18                                             F
19                                            F
20    +    +    +    +    +    +    +    +   F+    +
21                                          F
22                                           F
23                                         F
24                                          F
```

Table 2.3 DLM68 Short Term Forecast Report

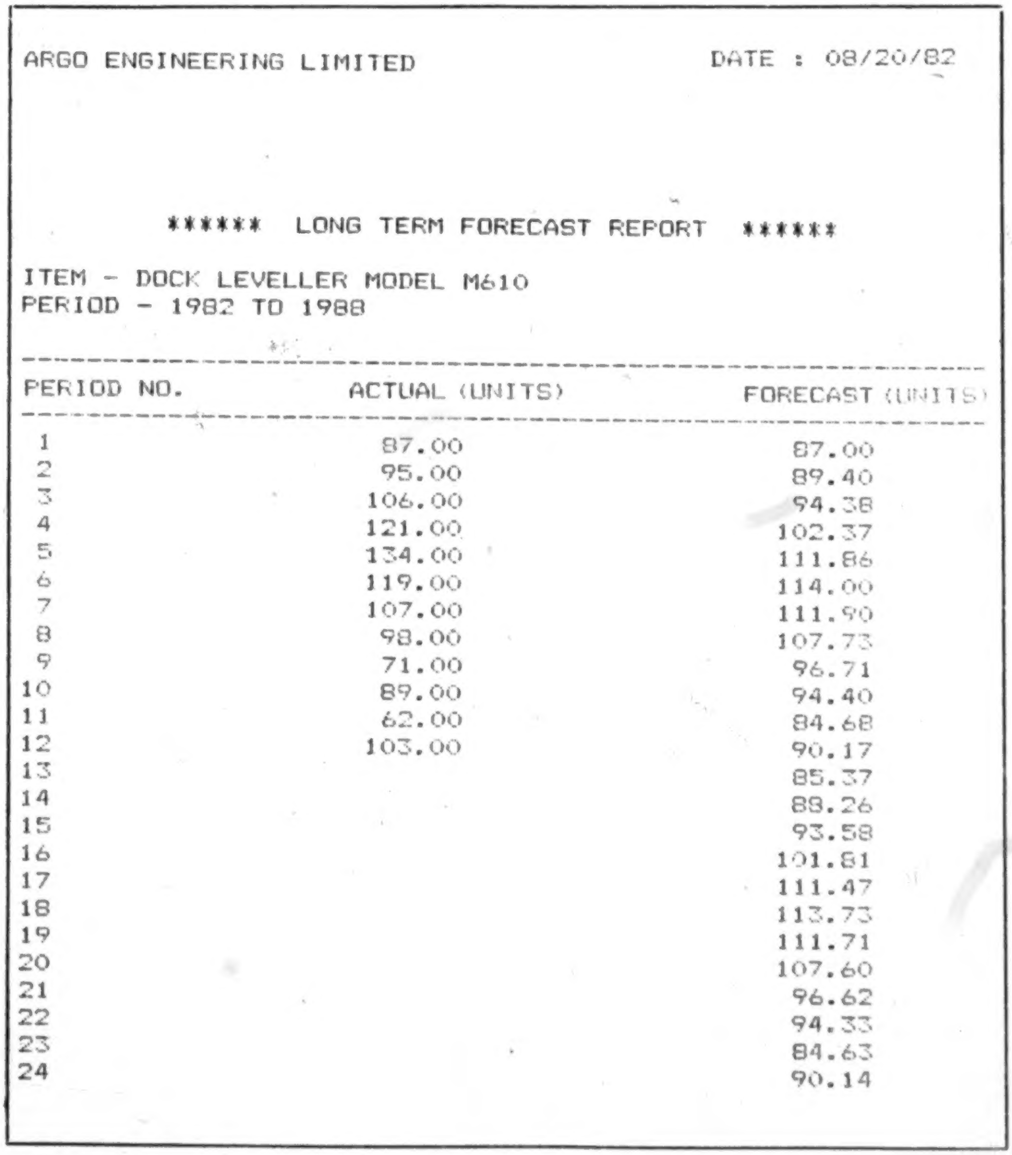


```
ARGO ENGINEERING LIMITED                         DATE : 08/20/82



       ******  SHORT TERM FORECAST REPORT  ******

ITEM - DOCK LEVELLER MODEL M68
PERIOD - AUG 1982 TO JULY 1983

-------------------------------------------------------------------
MONTH NO.          ACTUAL (UNITS)               FORECAST (UNITS)
-------------------------------------------------------------------
 1                    21.00                        21.00
 2                    20.00                        20.70
 3                    20.00                        20.49
 4                    21.00                        20.64
 5                    20.00                        20.45
 6                    21.00                        20.62
 7                    22.00                        21.03
 8                    20.00                        20.72
 9                    21.00                        20.80
10                    21.00                        20.86
11                    22.00                        21.20
12                    20.00                        20.84
13                                                 21.14
14                                                 20.80
15                                                 20.56
16                                                 20.69
17                                                 20.48
18                                                 20.64
19                                                 21.05
20                                                 20.73
21                                                 20.81
22                                                 20.87
23                                                 21.21
24                                                 20.85
```

Table 2.4 DLM68 Short Term Forecast Graph

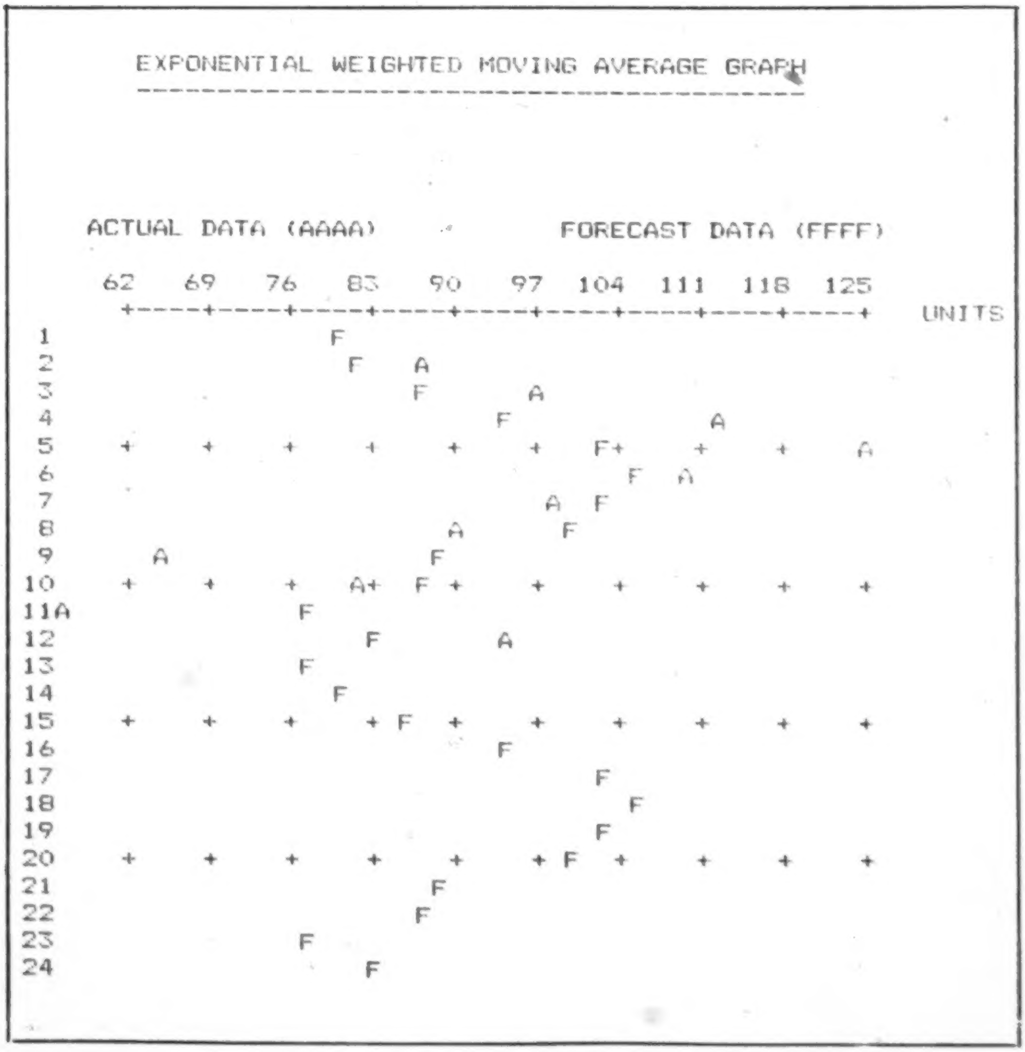
```
       EXPONENTIAL WEIGHTED MOVING AVERAGE GRAPH
       -----------------------------------------


    ACTUAL DATA (AAAA)           FORECAST DATA (FFFF)

     14   15   16   17   18   19   20   21   22   23
      +----+----+----+----+----+----+----+----+----+    UNITS
 1                                          F
 2                                   A    F
 3                                   A   F
 4                                        F A
 5    +    +    +    +    +    +    +A  F+    +    +
 6                                       F  A
 7                                          F      A
 8                                   A    F
 9                                         FA
10    +    +    +    +    +    +    +    + FA +    +
11                                           F     A
12                                   A     F
13                                           F
14                                         F
15    +    +    +    +    +    +    +    F    +    +
16                                        F
17                                      F
18                                       F
19                                          F
20    +    +    +    +    +    +    +    +F   +    +
21                                         F
22                                         F
23                                           F
24                                         F
```

Table 2.5 DLM610 Long Term Forecast Report



```
ARGO ENGINEERING LIMITED                           DATE : 08/20/82



       ******  LONG TERM FORECAST REPORT  ******

ITEM - DOCK LEVELLER MODEL M610
PERIOD - 1982 TO 1988
--------------------------------------------------------------------------
PERIOD NO.            ACTUAL (UNITS)                  FORECAST (UNITS)
--------------------------------------------------------------------------
 1                        87.00                        87.00
 2                        95.00                        89.40
 3                       106.00                        94.38
 4                       121.00                       102.37
 5                       134.00                       111.86
 6                       119.00                       114.00
 7                       107.00                       111.90
 8                        98.00                       107.73
 9                        71.00                        96.71
10                        89.00                        94.40
11                        62.00                        84.68
12                       103.00                        90.17
13                                                     85.37
14                                                     88.26
15                                                     93.58
16                                                    101.81
17                                                    111.47
18                                                    113.73
19                                                    111.71
20                                                    107.60
21                                                     96.62
22                                                     94.33
23                                                     84.63
24                                                     90.14
```

Table 2.6 DLM610 Long Term Forecast Graph



```
       EXPONENTIAL WEIGHTED MOVING AVERAGE GRAPH
       -----------------------------------------



    ACTUAL DATA (AAAA)           FORECAST DATA (FFFF)

     62   69   76   83   90   97  104  111  118  125
      +----+----+----+----+----+----+----+----+----+----+   UNITS
 1                 F
 2                  F   A
 3                      F      A
 4                           F            A
 5    +    +    +    +    +    +   F+    +    +    A
 6                                   F  A
 7                              A  F
 8                        A      F
 9      A                F
10    +    +    +   A+  F +    +    +    +    +    +
11A              F
12                   F       A
13               F
14                 F
15    +    +    +    + F  +    +    +    +    +    +
16                           F
17                                 F
18                                   F
19                                 F
20    +    +    +    +    +    + F  +    +    +    +
21                       F
22                      F
23               F
24                   F
```

Table 2.7 DLM610 Short Term Forecast Report

```
ARGO ENGINEERING LIMITED                              DATE : 08/20/82



         ******  SHORT TERM FORECAST REPORT  ******

ITEM - DOCK LEVELLER MODEL M610
PERIOD - AUG 1982 TO JULY 1983

-----------------------------------------------------------------------
MONTH NO.            ACTUAL (UNITS)                    FORECAST (UNITS)
-----------------------------------------------------------------------
  1                        9.00                              9.00
  2                       10.00                              9.30
  3                        9.00                              9.21
  4                       10.00                              9.45
  5                       12.00                             10.21
  6                       15.00                             11.65
  7                       18.00                             13.55
  8                       20.00                             15.49
  9                       23.00                             17.74
 10                       25.00                             19.92
 11                        7.00                             16.04
 12                        7.00                             13.33
 13                                                         13.93
 14                                                         12.75
 15                                                         11.63
 16                                                         11.14
 17                                                         11.40
 18                                                         12.48
 19                                                         14.13
 20                                                         15.89
 21                                                         18.03
 22                                                         20.12
 23                                                         16.18
 24                                                         13.43
```

Table 2.8 DLM610 Short Term Forecast Graph

```
         EXPONENTIAL WEIGHTED MOVING AVERAGE GRAPH
         -----------------------------------------


     ACTUAL DATA (AAAA)                 FORECAST DATA (FFFF)

        7     9    11    13    15    17    19    21    23    25
        +-----+-----+-----+-----+-----+-----+-----+-----+-----+   UNITS
 1       F
 2        F  A
 3       AF
 4        F  A
 5      +    F+    A+     +     +     +     +     +     +     +
 6               F          A
 7                     F              A
 8                             F             A
 9                                    F                A
10      +     +     +     +     +     +     +F    +     +     A
11A                             F
12A                    F
13                      F
14                   F
15      +     +  F  +     +     +     +     +     +     +     +
16              F
17              F
18                 F
19                       F
20      +     +     +     +     F     +     +     +     +     +
21                                     F
22                                           F
23                              F
24                     F
```

2.4.3 Discussion of Results

With reference to Table 2.1, the data under the heading "Actual" shows the past historical demand data entered by the user. The first twelve data points under the heading "Forecast" is the "smoothed" past historical demand data. The next twelve data points under the same heading represents the forecasted data. This explanation holds true for Tables 2.3, 2.5 and 2.7.

The past demand for Dock Leveller Model M68 is fairly constant for both the short and long term. The forecasted demand in either case is shown to be fairly constant as observed in Tables 2.1 and 2.3. The demand patterns are depicted more clearly in Tables 2.2 and 2.4.

The demand data points which are used to represent the historical demand for Dock Leveller Model M610 is hypothetical and assumed to follow a cyclical pattern. Tables 2.5 and 2.7 show the respective long and short term historical demand input data. The forecast is shown to follow a similar pattern. This is clearly depicted by Tables 2.6 and 2.8 respectively.

3. MASTER PRODUCTION SCHEDULE (MPS) MODEL

3.1 Master Production Schedule

The Master Production Schedule is defined by the American Production and Inventory Control Society (APICS) as a statement of what the company expects to manufacture [29].

The objectives of the Master Production Schedule are:

1. over the short horizon, to serve as a basis for the planning of material requirements, the production of components, the planning of order priorities and the planning of short term capacity requirements;
2. over the long horizon, to serve as the basis for estimating long term demands on the company's resources such as productive capacity (square footage, machine tools, manpower), warehousing capacity, engineering staff and cash;
3. to provide a mechanism to coordinate production planning and control, manufacturing, marketing, engineering and finance activities so that all can work together to achieve a common performance;
4. to provide a device to reconcile the needs of marketing with the capabilities of manufacturing;
5. to provide an overall measure of the ability of each major function in the business to execute a sound plan.

3.2 Establishment of a Master Production Schedule

The production planning and control department usually assigns the task of running the Master Production Schedule Model to the Master Scheduler. The step-by-step approach for developing a realistic Master Production Schedule is presented below:

1. For the first round, the long term forecast results for each end item is run through the Master Production Schedule Model. The Master Production Schedule Model produces reports for each end item, namely:
    - End Item File,
    - Long Term Master Production Schedule, and
    - Receipt List.
2. The next step is to check whether the company has the capacity to meet the Long Term Master Production Schedule. The output of the Long Term Master Production Schedule becomes the input into the Resource Requirements Planning Model.
3. The Master Production Schedule and Resource Requirements Planning reports are normally sent to the senior managers of the interfacing departments for approval.
4. Any revised Long Term Master Production Schedule will be resimulated through the Resource Requirements Planning Model to check for capacity availability. On agreement of the respective senior managers, the Long Term Master Production Schedule is fixed for a period of six months or for a period deemed appropriate by the senior

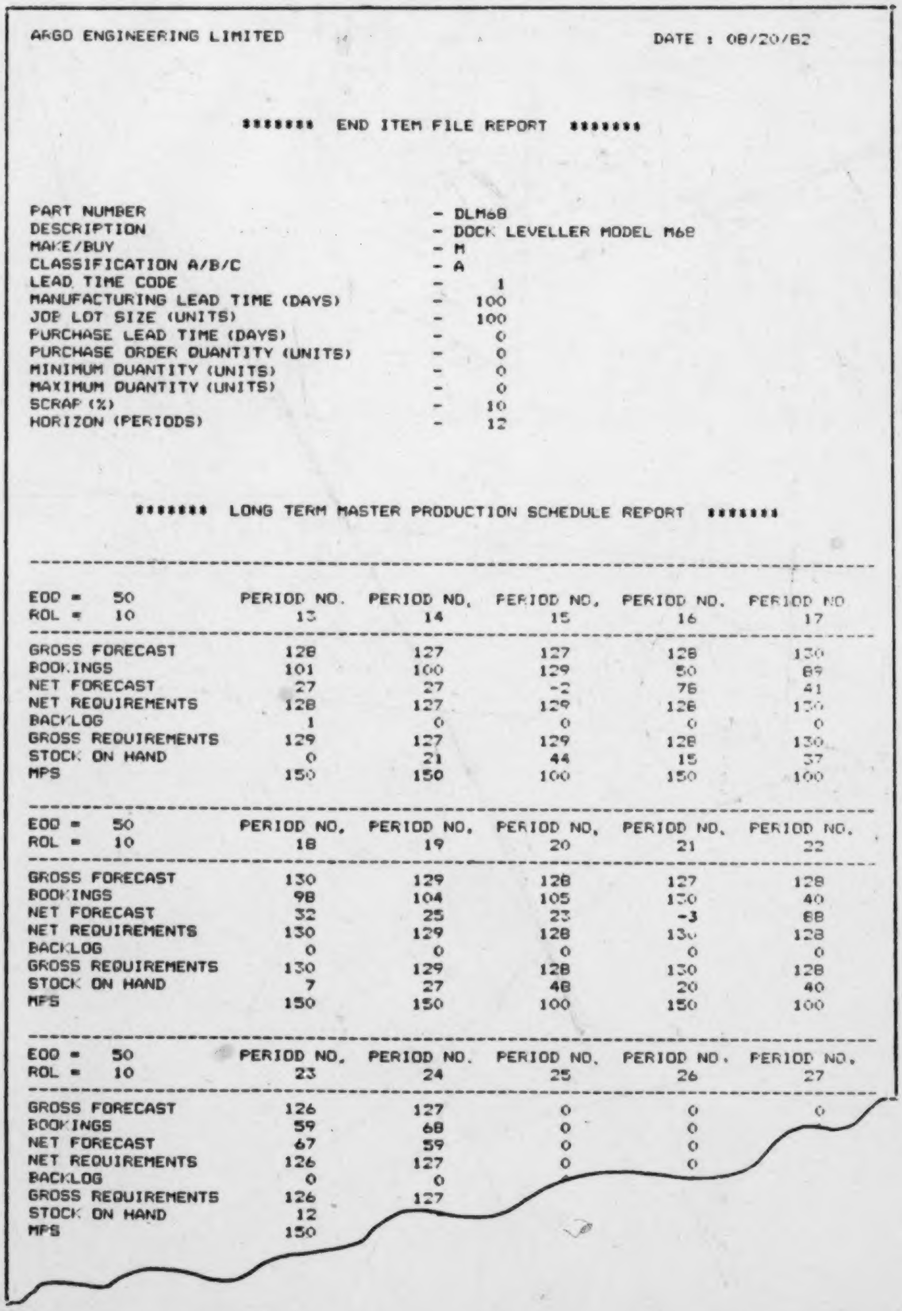
managers.

5. For the second round, the short term forecast results represent input into the Master Production Schedule Model. The Master Production Schedule Model outputs reports that serve as input data into the Material Requirements Planning Model and indirectly the Capacity Requirements Planning Model. The reports are:
    - End Item File,
    - Short Term Master Production Schedule, and
    - Receipt List.

   These reports are circulated to the senior managers of the interfacing departments for approval. In the event of a revision, the revised Short Term Master Production Schedule is resimulated through the Material Requirements Planning and Capacity Requirements Planning Models. The process is repeated until a Short Term Master Production Schedule which is realistic and agreeable to all the senior managers, or at least the majority of the senior managers is achieved. Once the Short Term Master Production Schedule is set, it is frozen for one month or for a period deemed appropriate by the senior managers. The format of the Long and Short Term Master Production Schedules are depicted in Tables 3.1 and 3.2.

Table 3.1

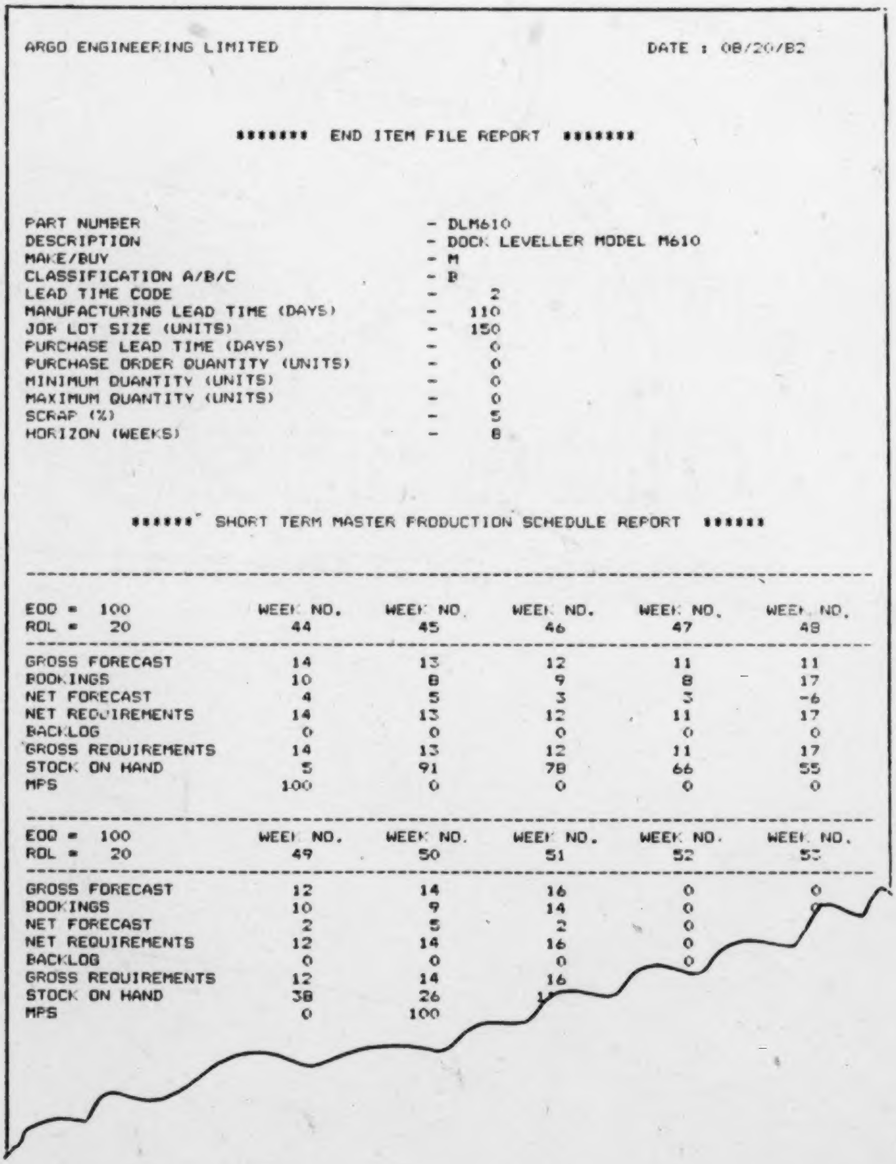
DLM68 Long Term Master Production Schedule Report Sample



```
ARGO ENGINEERING LIMITED                              DATE : 08/20/82


               *******  END ITEM FILE REPORT  *******


PART NUMBER                              - DLM68
DESCRIPTION                              - DOCK LEVELLER MODEL M68
MAKE/BUY                                 - M
CLASSIFICATION A/B/C                     - A
LEAD TIME CODE                           -    1
MANUFACTURING LEAD TIME (DAYS)           -   100
JOB LOT SIZE (UNITS)                     -   100
PURCHASE LEAD TIME (DAYS)                -     0
PURCHASE ORDER QUANTITY (UNITS)          -     0
MINIMUM QUANTITY (UNITS)                 -     0
MAXIMUM QUANTITY (UNITS)                 -     0
SCRAP (%)                                -    10
HORIZON (PERIODS)                        -    12


         *******  LONG TERM MASTER PRODUCTION SCHEDULE REPORT  *******

-------------------------------------------------------------------------------
EOQ =    50          PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO
ROL =    10              13          14          15          16          17
-------------------------------------------------------------------------------
GROSS FORECAST          128         127         127         128         130
BOOKINGS                101         100         129          50          89
NET FORECAST             27          27          -2          76          41
NET REQUIREMENTS        128         127         129         128         130
BACKLOG                   1           0           0           0           0
GROSS REQUIREMENTS      129         127         129         128         130
STOCK ON HAND             0          21          44          15          37
MPS                     150         150         100         150         100

-------------------------------------------------------------------------------
EOQ =    50          PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =    10              18          19          20          21          22
-------------------------------------------------------------------------------
GROSS FORECAST          130         129         128         127         128
BOOKINGS                 98         104         105         130          40
NET FORECAST             32          25          23          -3          88
NET REQUIREMENTS        130         129         128         130         128
BACKLOG                   0           0           0           0           0
GROSS REQUIREMENTS      130         129         128         130         128
STOCK ON HAND             7          27          48          20          40
MPS                     150         150         100         150         100

-------------------------------------------------------------------------------
EOQ =    50          PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =    10              23          24          25          26          27
-------------------------------------------------------------------------------
GROSS FORECAST          126         127           0           0           0
BOOKINGS                 59          68           0           0
NET FORECAST             67          59           0           0
NET REQUIREMENTS        126         127           0           0
BACKLOG                   0           0
GROSS REQUIREMENTS      126         127
STOCK ON HAND            12
MPS                     150
```

Table 3.2

DLM610 Short Term Master Production Schedule Report Sample



```
ARGO ENGINEERING LIMITED                                          DATE : 08/20/82


                       *******  END ITEM FILE REPORT  *******


PART NUMBER                                      - DLM610
DESCRIPTION                                      - DOCK LEVELLER MODEL M610
MAKE/BUY                                         - M
CLASSIFICATION A/B/C                             - B
LEAD TIME CODE                                   -      2
MANUFACTURING LEAD TIME (DAYS)                   -    110
JOB LOT SIZE (UNITS)                             -    150
PURCHASE LEAD TIME (DAYS)                        -      0
PURCHASE ORDER QUANTITY (UNITS)                  -      0
MINIMUM QUANTITY (UNITS)                         -      0
MAXIMUM QUANTITY (UNITS)                         -      0
SCRAP (%)                                        -      5
HORIZON (WEEKS)                                  -      8


          ******  SHORT TERM MASTER PRODUCTION SCHEDULE REPORT  ******

----------------------------------------------------------------------------------

EOQ =  100            WEEK NO.     WEEK NO.     WEEK NO.     WEEK NO.     WEEK NO.
ROL =   20               44           45           46           47           48
----------------------------------------------------------------------------------
GROSS FORECAST           14           13           12           11           11
BOOKINGS                 10            8            9            8           17
NET FORECAST              4            5            3            3           -6
NET REQUIREMENTS         14           13           12           11           17
BACKLOG                   0            0            0            0            0
GROSS REQUIREMENTS       14           13           12           11           17
STOCK ON HAND             5           91           78           66           55
MPS                     100            0            0            0            0

----------------------------------------------------------------------------------
EOQ =  100            WEEK NO.     WEEK NO.     WEEK NO.     WEEK NO.     WEEK NO.
ROL =   20               49           50           51           52           53
----------------------------------------------------------------------------------
GROSS FORECAST           12           14           16            0            0
BOOKINGS                 10            9           14            0            0
NET FORECAST              2            5            2            0
NET REQUIREMENTS         12           14           16            0
BACKLOG                   0            0            0            0
GROSS REQUIREMENTS       12           14           16
STOCK ON HAND            38           26           1
MPS                       0          100
```

3.3 The Master Production Schedule Computer Program

The model design is based on the following rules:

1. The forecasted demand is accurate for the period when the Master Production Schedule is frozen. However, the discrepancies are adjusted once the "freeze" is over. This means that the Master Production Schedule frozen for the next period makes use of actual data for replanning.
2. Initially, the company may utilize the Economic Order Quantity formula as the most reasonable lot-sizing technique. Over time, based on experience the company may employ other techniques as deemed appropriate.
3. Backlog is permitted and if cancellation of orders occur during the "freeze" period, it is not reflected until the next replanning period.
4. The forecasted demand can be divided into equal lots per period of time. This implies that if the forecast is four units per month, it is equivalent to one unit per week per month.

3.3.1 Model Algorithm

The flow diagram of the Master Production Schedule Model is shown in Figure 3.1.

The variables used in the flow diagram are defined in Appendix A.

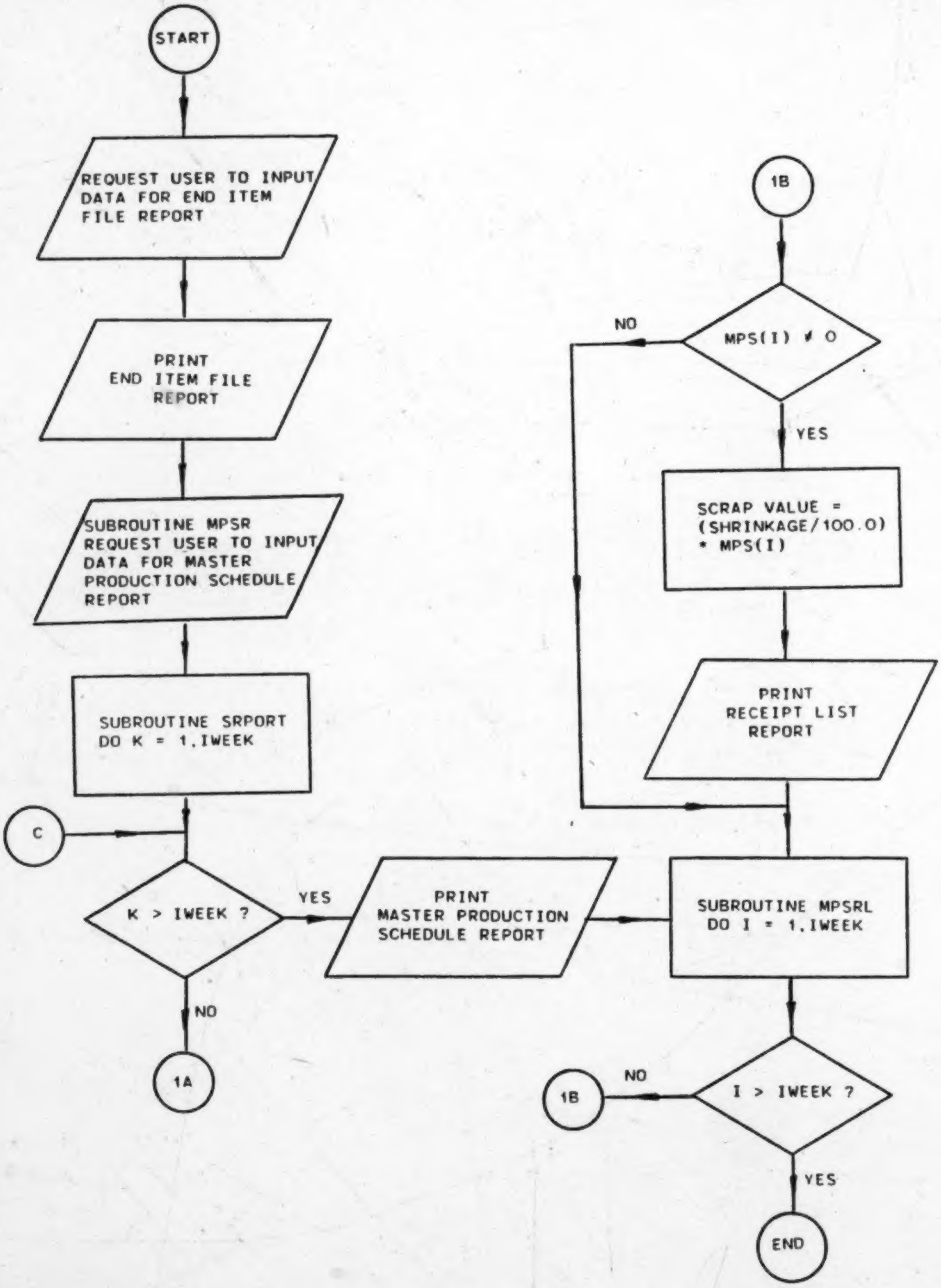

START
REQUEST USER TO INPUT DATA FOR END ITEM FILE REPORT
PRINT END ITEM FILE REPORT
SUBROUTINE MPSR REQUEST USER TO INPUT DATA FOR MASTER PRODUCTION SCHEDULE REPORT
SUBROUTINE SRPORT DO K = 1,IWEEK
C
K > IWEEK ?
YES
NO
1A
PRINT MASTER PRODUCTION SCHEDULE REPORT
SUBROUTINE MPSRL DO I = 1,IWEEK
I > IWEEK ?
NO
1B
YES
END
1B
MPS(I) ≠ 0
NO
YES
SCRAP VALUE = (SHRINKAGE/100.0) * MPS(I)
PRINT RECEIPT LIST REPORT

Figure 3.1 Master Production Schedule Model Flow Chart

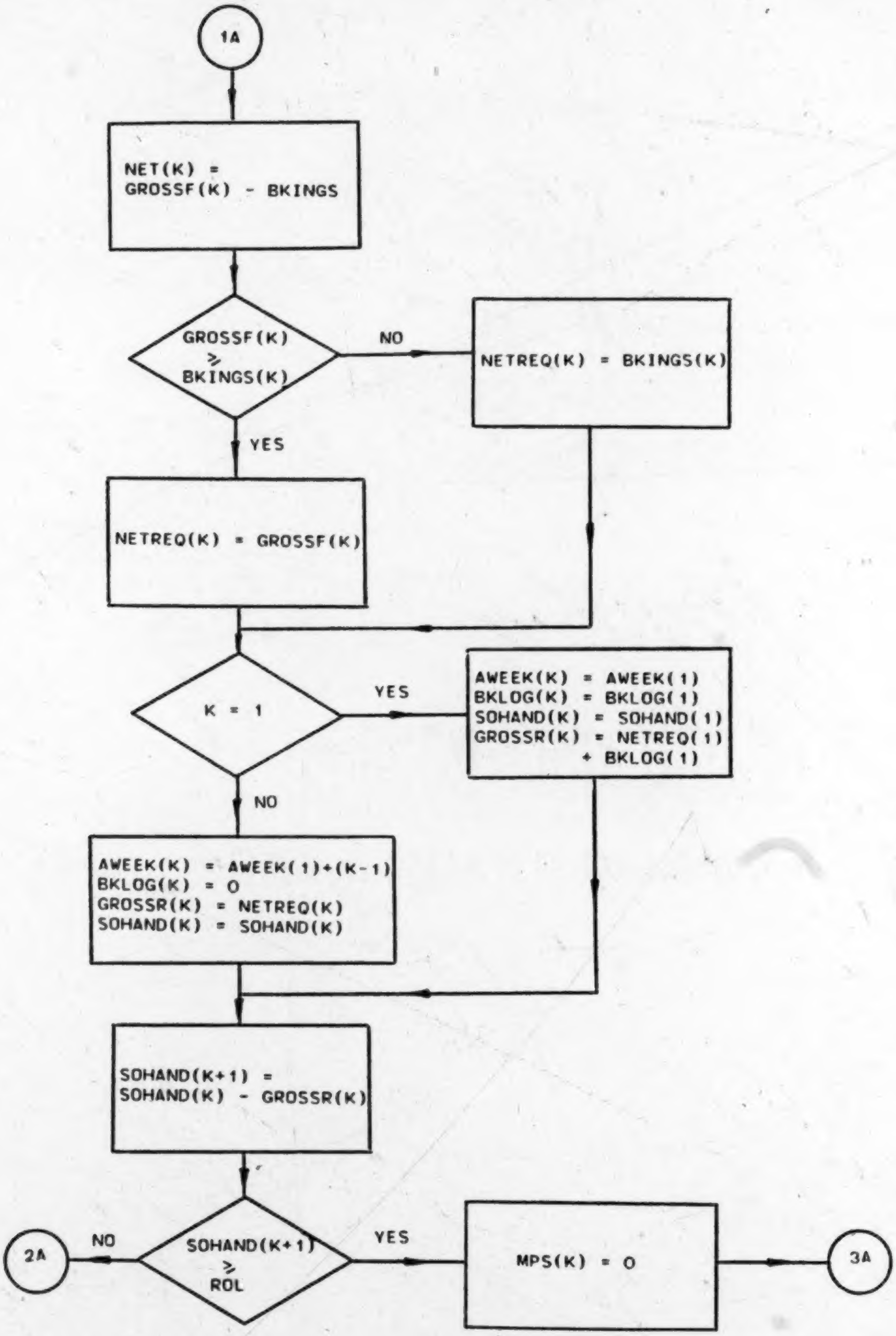


Figure 3.1 Continued

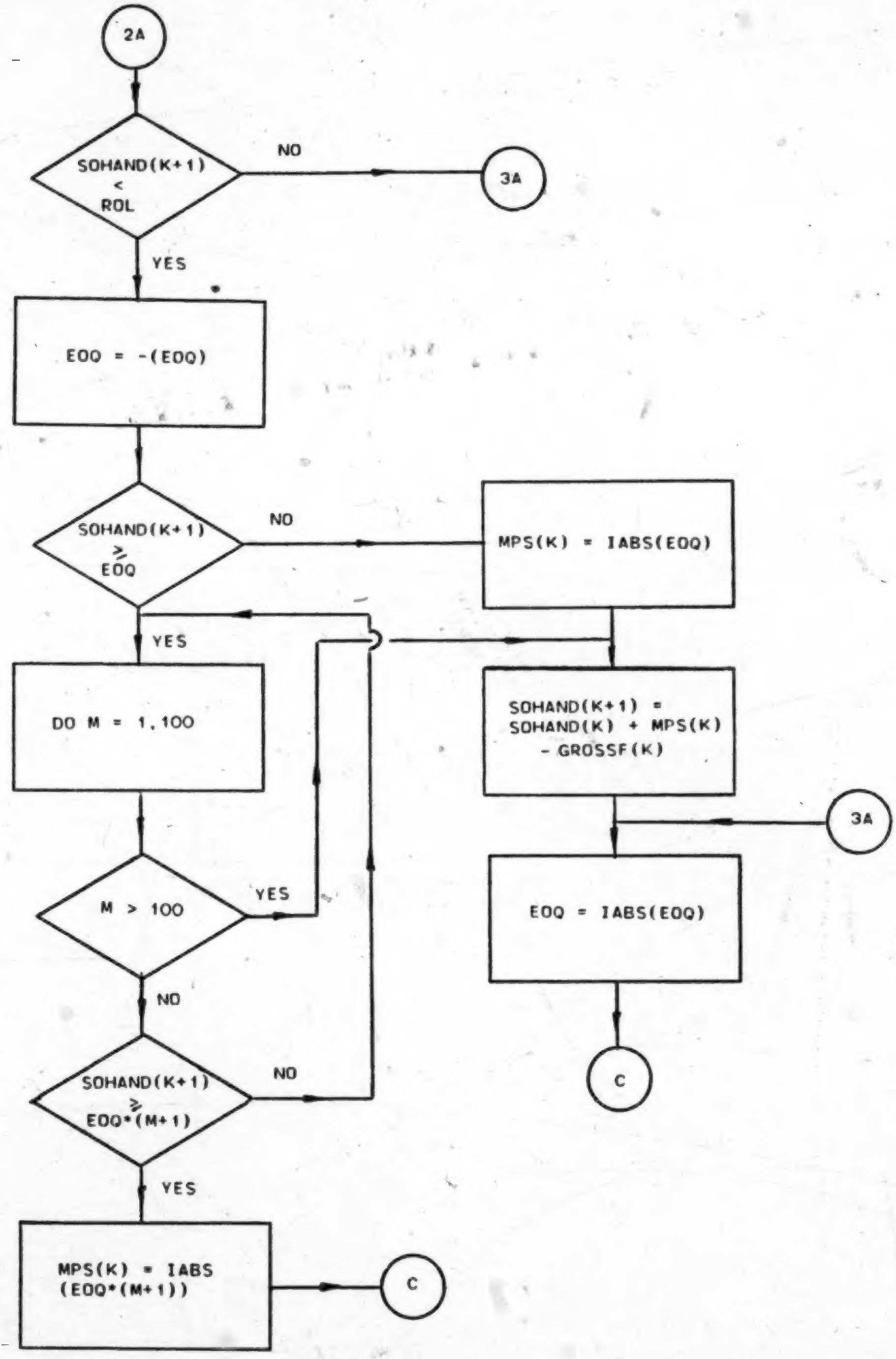


Figure 3.1 Continued

The algorithmic flow of the Master Production Schedule Model is explained below:

1. The user is required to input data for the formatting of the End Item File Report. The End Item File Report identifies and displays relevant information pertaining to the end item in question. The End Item File Report is printed on the line printer.
2. Next, the user is required to key in data for the compilation of the Master Production Schedule Report. The program manipulates the input data, calculates and formats the Master Production Schedule. The Master Production Schedule is printed on the line printer.
3. The program then reads the Master Production Schedule, picks out the necessary information and performs the required computations. The resultant output is printed on the line printer as the Receipt List Report.

3.4 Testing the Model

To produce the Long Term Master Production Schedule Report, the results of the Long Term Forecast Report for each product line for the next six years were input into the Master Production Schedule Model. The user gets the Master Production Schedule Model into interactive mode by typing in the file name **MPSM** . The user is required to key in the data requested.

3.4.1 Interactive Input Data Format

The displays on the visual display unit are as follows:

```
***********************************
* MASTER PRODUCTION SCHEDULE MODEL *
***********************************

*Enter data for End Item File Report*
Enter today's date (mm/dd/yy):
08/22/82
Enter part number (10 alphanumeric values):
DLM68
Enter description (40 alphanumeric values):
Dock Leveller Model M68
Enter make or buy (M/B):
M
Enter classification (A/B/C):
A
Enter lead time code (1/2/3):
1
Enter manufacturing lead time in days (3 digits):
100
Enter job lot size in units (4 digits):
0100
Enter purchasing lead time in days (3 digits):
000
Enter purchase order quantity in units (digits):
```

```
00000

Enter minimum quantity in units (5 digits):

00000

Enter maximum quantity in units (5 digits):

00000

Enter scrap in % (4 digits):

0010

Enter horizon in weeks or periods (3 digits):

012

***** PRINTING .......


*Enter data for Master Production Schedule Report*

Enter long or short term:

Press 1 for long term

Press 2 for short term

1

Enter period or week:

Press 1 for period

Press 2 for week

1

Enter number of weeks or periods desired:

12

Enter beginning week or period no. (2 digits):

13

Enter economic order quantity in units (4 digits):

0050

Enter reorder level in units (4 digits):
```

```
0010
Enter backlog and stock on hand in units
(2 digits, a space, followed by 2 digits):
01 00
Enter gross forecast and bookings for those weeks or periods
desired in units
(5 digits, a space, followed by another 5 digits):
00128 00101
00127 00100
00127 00129
00128 00050
00130 00089
00130 00098
00129 00104
00128 00105
00127 00130
00128 00040
00126 00059
00127 00068
**** PRINTING ......
```

The user may enter "2" following the prompts:

```
Enter long or short term:
Press 1 for long term
Press 2 for short term
2
Enter period or week:
Press 1 for period
```

Press 2 for week

2

The data requests which follow will appear in the same sequence as above, commencing from:

Enter number of weeks or periods desired:

The difference is in the output data format.

3.4.2 Output Data Format

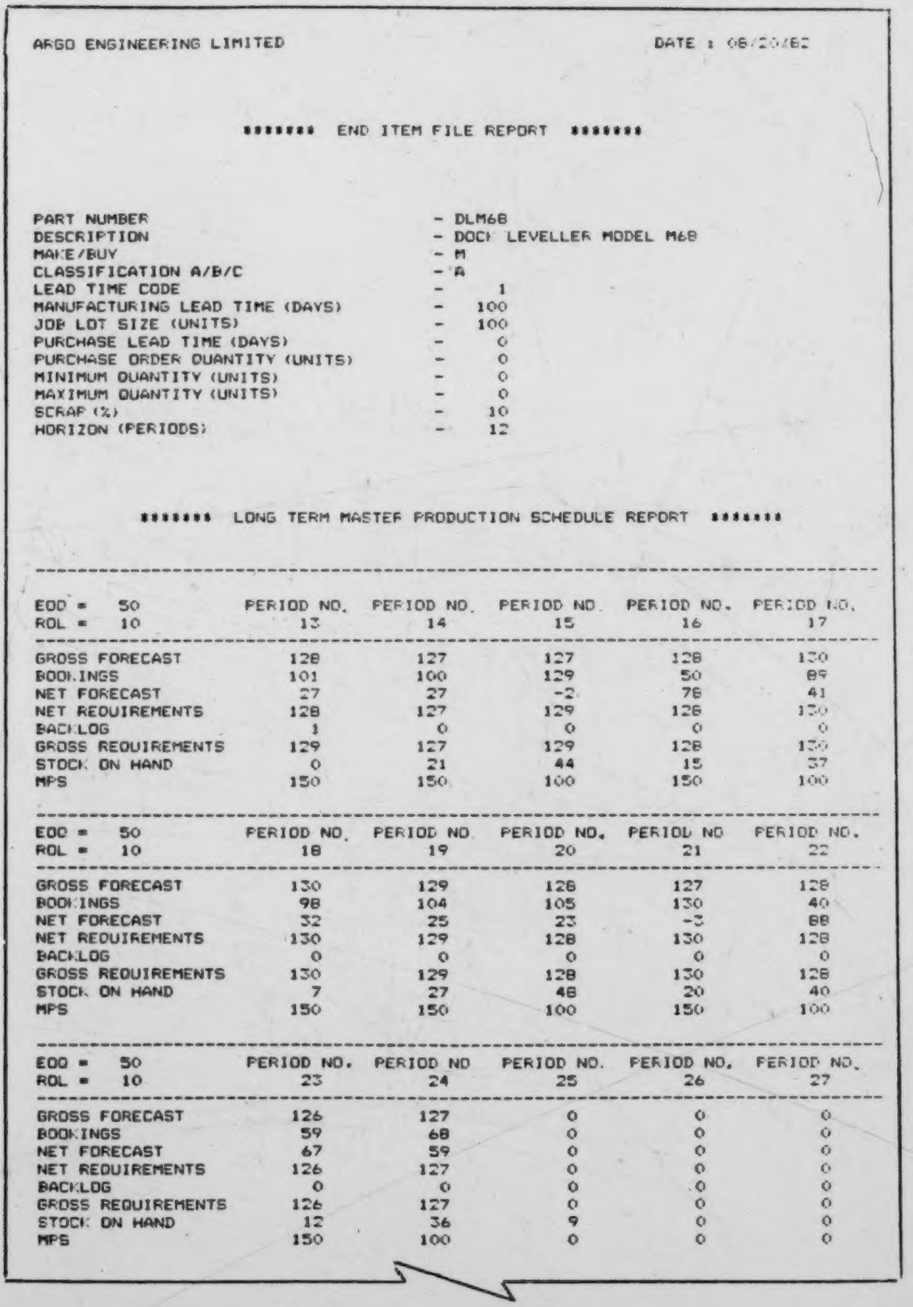
In the first instance where "1" is entered for both "long term" and "period", the results are shown in Table 3.3. Table 3.4 shows the output as a result of entering "2" for both "short term" and "week".

The Master Production Schedule is tested with hypothetical data pertaining to a different product; Dock Leveller Model M610. The objective is to compare the different sets of results as a means of highlighting the effectiveness of the model. The results of the second test are shown in Tables 3.5 and 3.6.

The purpose of the End Item File Report is to identify the end item completely. The information is thus made readily available to management who can make use of it as reference notes for making decisions during meetings.

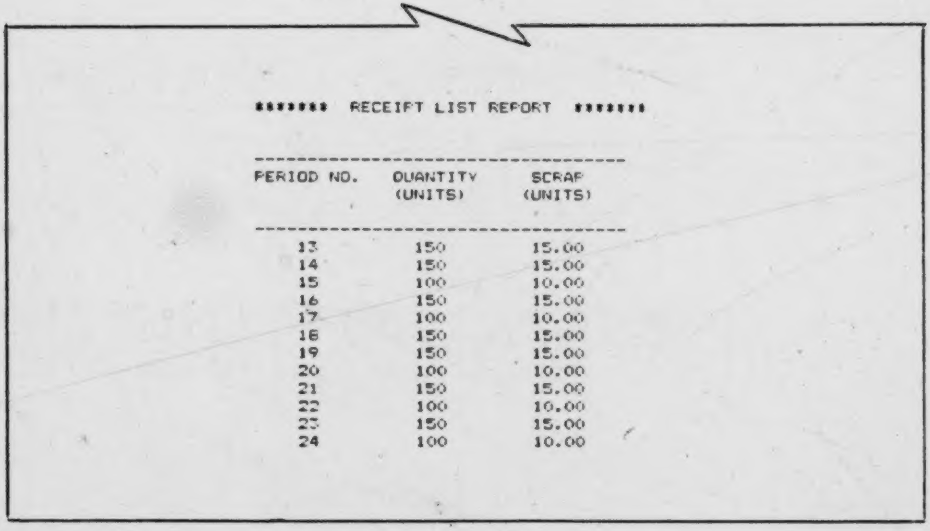
The Long and Short Term Master Production Schedules are the most important outputs of the Master Production Schedule Model. The Long Term Master Production Schedule becomes the input data into the Resource Requirements Planning Model. The results of the Resource Requirements Plan are used to justify changes to the Long Term Master Production Schedule as may be required during meetings of senior managers. The Short Term Master Production Schedule is used to "drive" the Material Requirements Planning sub-system.

Table 3.3 DLM68 Long Term Master Production Schedule Report



```
ARGO ENGINEERING LIMITED                                    DATE : 06/20/82


                    *******  END ITEM FILE REPORT  *******


PART NUMBER                              - DLM68
DESCRIPTION                              - DOCK LEVELLER MODEL M68
MAKE/BUY                                 - M
CLASSIFICATION A/B/C                     - A
LEAD TIME CODE                           -      1
MANUFACTURING LEAD TIME (DAYS)           -    100
JOB LOT SIZE (UNITS)                     -    100
PURCHASE LEAD TIME (DAYS)                -      0
PURCHASE ORDER QUANTITY (UNITS)          -      0
MINIMUM QUANTITY (UNITS)                 -      0
MAXIMUM QUANTITY (UNITS)                 -      0
SCRAP (%)                                -     10
HORIZON (PERIODS)                        -     12


          *******  LONG TERM MASTER PRODUCTION SCHEDULE REPORT  *******

---------------------------------------------------------------------------------
EOQ =   50           PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =   10               13          14          15          16          17
---------------------------------------------------------------------------------
GROSS FORECAST          128         127         127         128         130
BOOKINGS                101         100         129          50          89
NET FORECAST             27          27          -2          78          41
NET REQUIREMENTS        128         127         129         128         130
BACKLOG                   1           0           0           0           0
GROSS REQUIREMENTS      129         127         129         128         130
STOCK ON HAND             0          21          44          15          37
MPS                     150         150         100         150         100

---------------------------------------------------------------------------------
EOQ =   50           PERIOD NO.  PERIOD NO   PERIOD NO.  PERIOD NO   PERIOD NO.
ROL =   10               18          19          20          21          22
---------------------------------------------------------------------------------
GROSS FORECAST          130         129         128         127         128
BOOKINGS                 98         104         105         130          40
NET FORECAST             32          25          23          -3          88
NET REQUIREMENTS        130         129         128         130         128
BACKLOG                   0           0           0           0           0
GROSS REQUIREMENTS      130         129         128         130         128
STOCK ON HAND             7          27          48          20          40
MPS                     150         150         100         150         100

---------------------------------------------------------------------------------
EOQ =   50           PERIOD NO.  PERIOD NO   PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =   10               23          24          25          26          27
---------------------------------------------------------------------------------
GROSS FORECAST          126         127           0           0           0
BOOKINGS                 59          68           0           0           0
NET FORECAST             67          59           0           0           0
NET REQUIREMENTS        126         127           0           0           0
BACKLOG                   0           0           0           0           0
GROSS REQUIREMENTS      126         127           0           0           0
STOCK ON HAND            12          36           9           0           0
MPS                     150         100           0           0           0
```

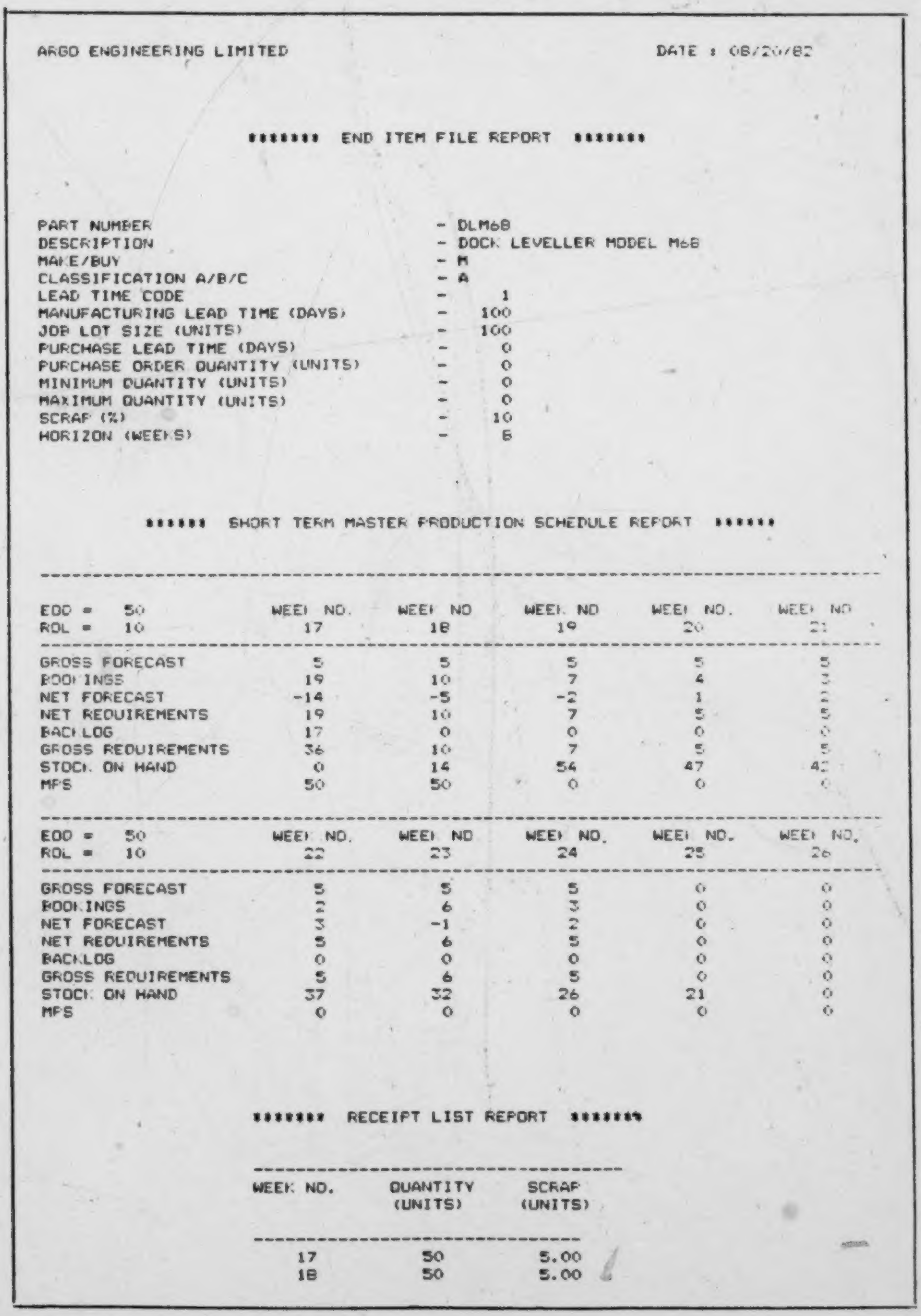
Table 3.3 Continued



```
*******  RECEIPT LIST REPORT  *******

------------------------------------
PERIOD NO.   QUANTITY     SCRAP
              (UNITS)    (UNITS)

------------------------------------
    13          150        15.00
    14          150        15.00
    15          100        10.00
    16          150        15.00
    17          100        10.00
    18          150        15.00
    19          150        15.00
    20          100        10.00
    21          150        15.00
    22          100        10.00
    23          150        15.00
    24          100        10.00
```

Table 3.4

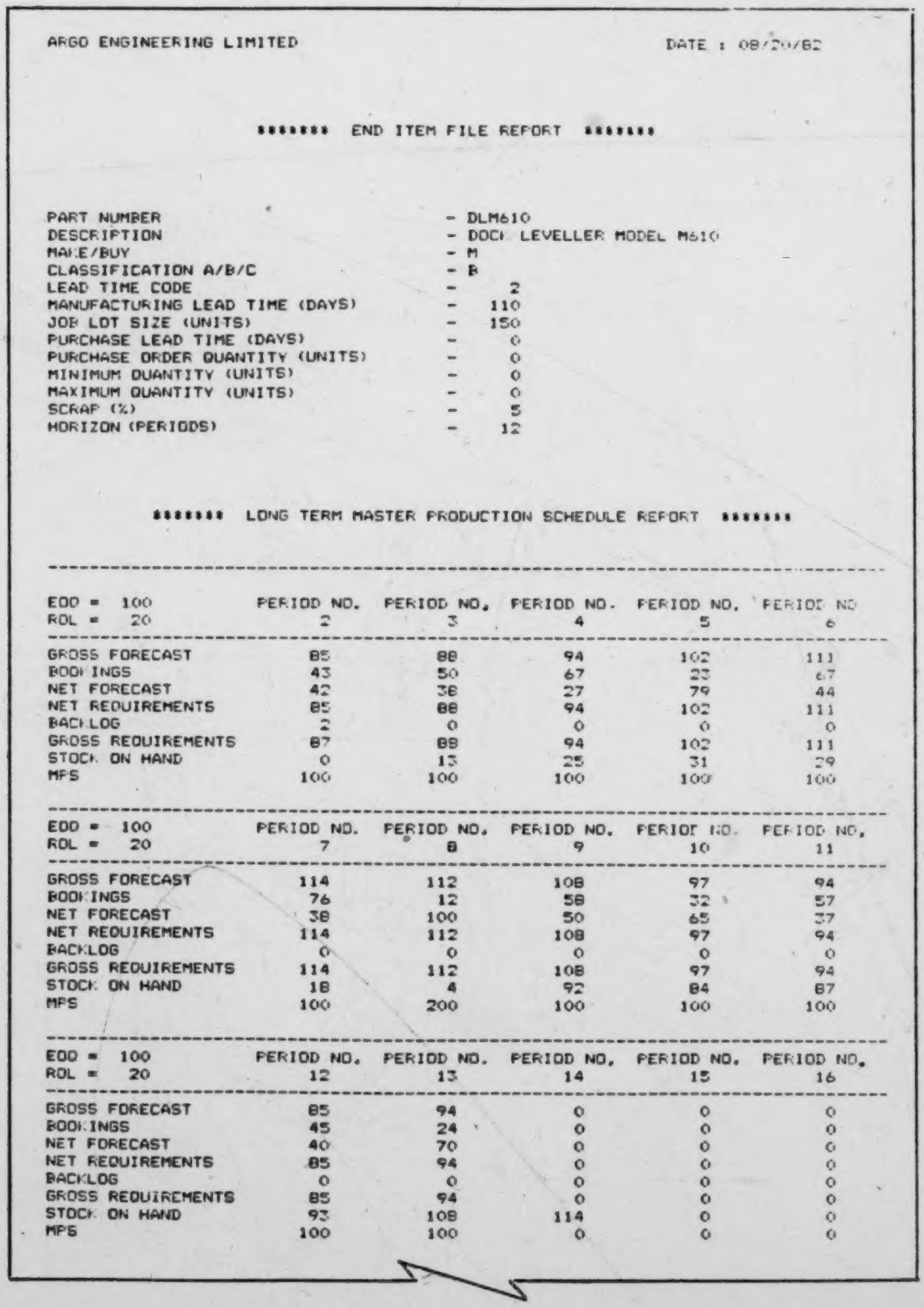
DLM68 Short Term Master Production Schedule Report



```
ARGO ENGINEERING LIMITED                                    DATE : 08/20/82


                  *******  END ITEM FILE REPORT  *******


PART NUMBER                               - DLM68
DESCRIPTION                               - DOCK LEVELLER MODEL M68
MAKE/BUY                                  - M
CLASSIFICATION A/B/C                      - A
LEAD TIME CODE                            -     1
MANUFACTURING LEAD TIME (DAYS)            -   100
JOB LOT SIZE (UNITS)                      -   100
PURCHASE LEAD TIME (DAYS)                 -     0
PURCHASE ORDER QUANTITY (UNITS)           -     0
MINIMUM QUANTITY (UNITS)                  -     0
MAXIMUM QUANTITY (UNITS)                  -     0
SCRAP (%)                                 -    10
HORIZON (WEEKS)                           -     6


         ******  SHORT TERM MASTER PRODUCTION SCHEDULE REPORT  ******

-------------------------------------------------------------------------------
EOQ =   50           WEEK NO.    WEEK NO     WEEK NO     WEEK NO.    WEEK NO
ROL =   10              17          18          19          20          21
-------------------------------------------------------------------------------
GROSS FORECAST           5           5           5           5           5
BOOKINGS                19          10           7           4           3
NET FORECAST           -14          -5          -2           1           2
NET REQUIREMENTS        19          10           7           5           5
BACKLOG                 17           0           0           0           0
GROSS REQUIREMENTS      36          10           7           5           5
STOCK ON HAND            0          14          54          47          42
MPS                     50          50           0           0           0

-------------------------------------------------------------------------------
EOQ =   50           WEEK NO.    WEEK NO     WEEK NO.    WEEK NO.    WEEK NO.
ROL =   10              22          23          24          25          26
-------------------------------------------------------------------------------
GROSS FORECAST           5           5           5           0           0
BOOKINGS                 2           6           3           0           0
NET FORECAST             3          -1           2           0           0
NET REQUIREMENTS         5           6           5           0           0
BACKLOG                  0           0           0           0           0
GROSS REQUIREMENTS       5           6           5           0           0
STOCK ON HAND           37          32          26          21           0
MPS                      0           0           0           0           0


                  *******  RECEIPT LIST REPORT  *******

                  -----------------------------------
                  WEEK NO.     QUANTITY     SCRAP
                                (UNITS)     (UNITS)

                  ------------------------------
                     17           50        5.00
                     18           50        5.00
```

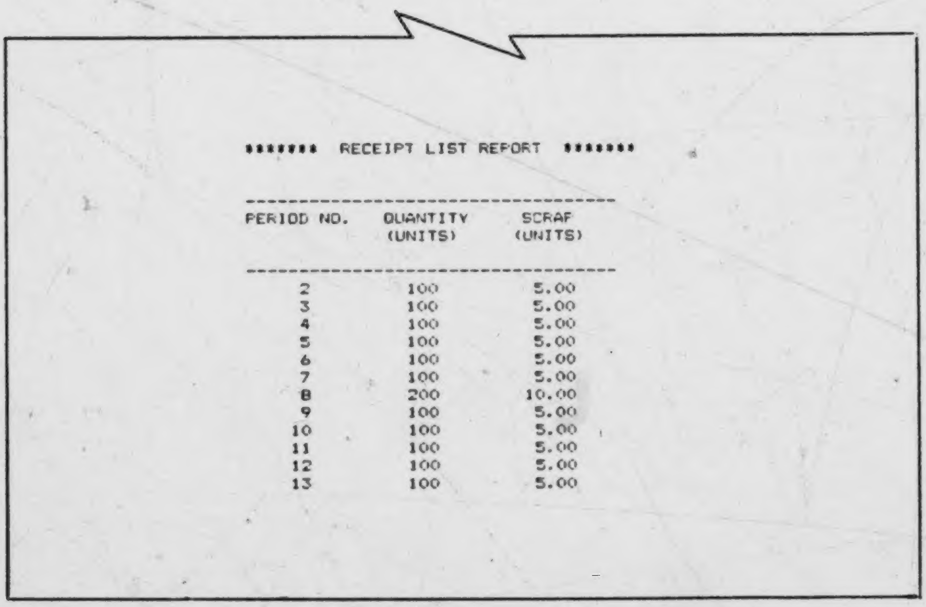
Table 3.5

DLM610 Long Term Master Production Schedule Report



```
ARGO ENGINEERING LIMITED                                    DATE : 08/20/82


                    *******  END ITEM FILE REPORT  *******


PART NUMBER                              - DLM610
DESCRIPTION                              - DOCK LEVELLER MODEL M610
MAKE/BUY                                 - M
CLASSIFICATION A/B/C                     - B
LEAD TIME CODE                           -     2
MANUFACTURING LEAD TIME (DAYS)           -   110
JOB LOT SIZE (UNITS)                     -   150
PURCHASE LEAD TIME (DAYS)                -     0
PURCHASE ORDER QUANTITY (UNITS)          -     0
MINIMUM QUANTITY (UNITS)                 -     0
MAXIMUM QUANTITY (UNITS)                 -     0
SCRAP (%)                                -     5
HORIZON (PERIODS)                        -    12


          *******  LONG TERM MASTER PRODUCTION SCHEDULE REPORT  *******

---------------------------------------------------------------------------------
EOQ =  100           PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO
ROL =   20                2           3           4           5           6
---------------------------------------------------------------------------------
GROSS FORECAST            85          88          94         102         111
BOOKINGS                  43          50          67          23          67
NET FORECAST              42          38          27          79          44
NET REQUIREMENTS          85          88          94         102         111
BACKLOG                    2           0           0           0           0
GROSS REQUIREMENTS        87          88          94         102         111
STOCK ON HAND              0          13          25          31          29
MPS                      100         100         100         100         100

---------------------------------------------------------------------------------
EOQ =  100           PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =   20                7           8           9          10          11
---------------------------------------------------------------------------------
GROSS FORECAST           114         112         108          97          94
BOOKINGS                  76          12          58          32          57
NET FORECAST              38         100          50          65          37
NET REQUIREMENTS         114         112         108          97          94
BACKLOG                    0           0           0           0           0
GROSS REQUIREMENTS       114         112         108          97          94
STOCK ON HAND             18           4          92          84          87
MPS                      100         200         100         100         100

---------------------------------------------------------------------------------
EOQ =  100           PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.  PERIOD NO.
ROL =   20               12          13          14          15          16
---------------------------------------------------------------------------------
GROSS FORECAST            85          94           0           0           0
BOOKINGS                  45          24           0           0           0
NET FORECAST              40          70           0           0           0
NET REQUIREMENTS          85          94           0           0           0
BACKLOG                    0           0           0           0           0
GROSS REQUIREMENTS        85          94           0           0           0
STOCK ON HAND             93         108         114           0           0
MPS                      100         100           0           0           0
```

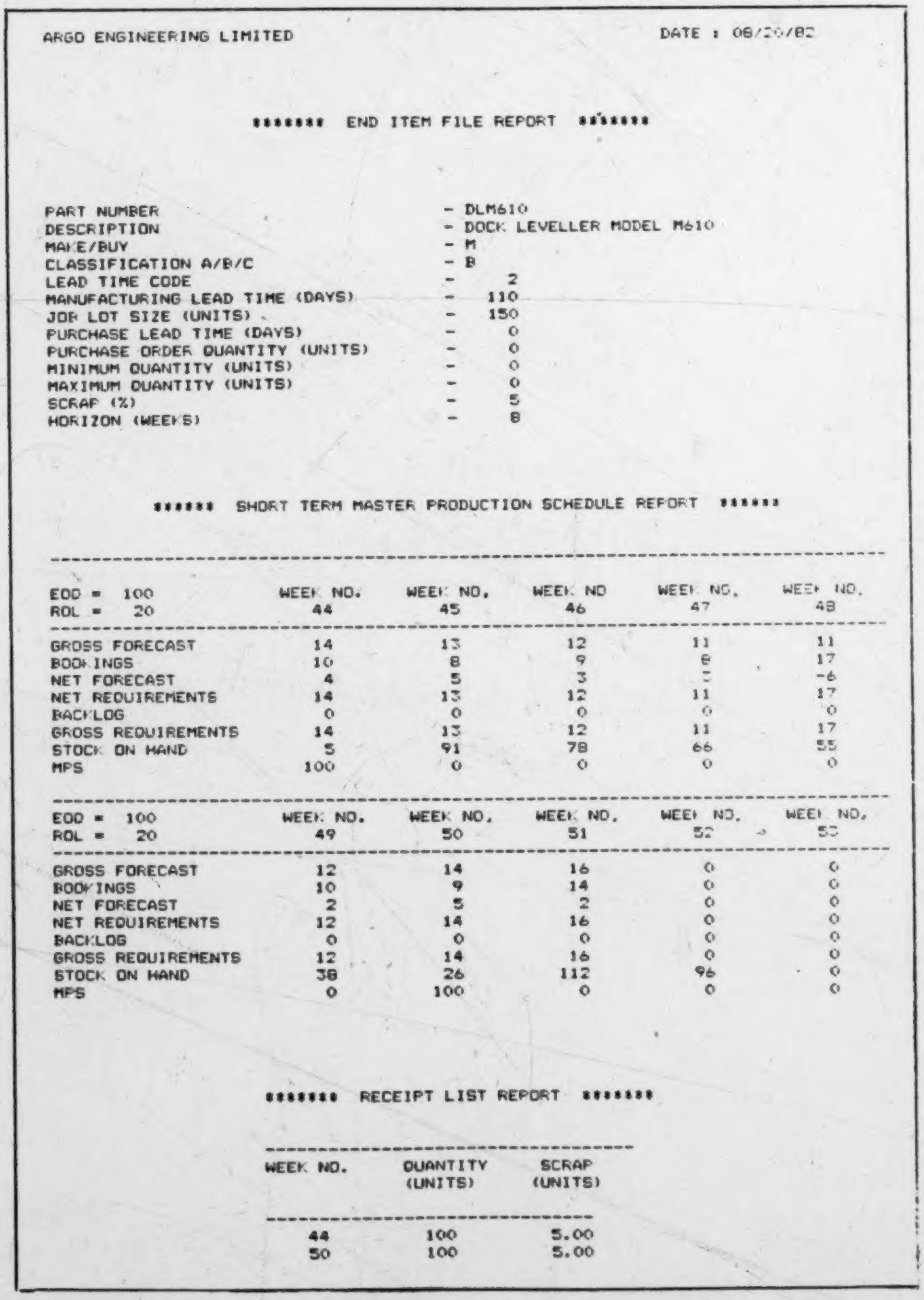
Table 3.5 Continued



```
********  RECEIPT LIST REPORT  ********

------------------------------------------
PERIOD NO.   QUANTITY     SCRAP
              (UNITS)     (UNITS)

------------------------------------------
     2          100         5.00
     3          100         5.00
     4          100         5.00
     5          100         5.00
     6          100         5.00
     7          100         5.00
     8          200        10.00
     9          100         5.00
    10          100         5.00
    11          100         5.00
    12          100         5.00
    13          100         5.00
```

Table 3.6

DLM610 Short Term Master Production Schedule Report



```
ARGO ENGINEERING LIMITED                                        DATE : 08/20/82


                    *******  END ITEM FILE REPORT  *******


PART NUMBER                                - DLM610
DESCRIPTION                                - DOCK LEVELLER MODEL M610
MAKE/BUY                                   - M
CLASSIFICATION A/B/C                       - B
LEAD TIME CODE                             -     2
MANUFACTURING LEAD TIME (DAYS)             -   110
JOB LOT SIZE (UNITS)                       -   150
PURCHASE LEAD TIME (DAYS)                  -     0
PURCHASE ORDER QUANTITY (UNITS)            -     0
MINIMUM QUANTITY (UNITS)                   -     0
MAXIMUM QUANTITY (UNITS)                   -     0
SCRAP (%)                                  -     5
HORIZON (WEEKS)                            -     8


          ******  SHORT TERM MASTER PRODUCTION SCHEDULE REPORT  ******

------------------------------------------------------------------------------
EOQ =  100            WEEK NO.     WEEK NO.     WEEK NO     WEEK NO.    WEEK NO.
ROL =   20               44           45           46          47          48
------------------------------------------------------------------------------
GROSS FORECAST           14           13           12          11          11
BOOKINGS                 10            8            9           8          17
NET FORECAST              4            5            3           3          -6
NET REQUIREMENTS         14           13           12          11          17
BACKLOG                   0            0            0           0           0
GROSS REQUIREMENTS       14           13           12          11          17
STOCK ON HAND             5           91           78          66          55
MPS                     100            0            0           0           0

------------------------------------------------------------------------------
EOQ =  100            WEEK NO.     WEEK NO.     WEEK NO.    WEEK NO.    WEEK NO.
ROL =   20               49           50           51          52          53
------------------------------------------------------------------------------
GROSS FORECAST           12           14           16           0           0
BOOKINGS                 10            9           14           0           0
NET FORECAST              2            5            2           0           0
NET REQUIREMENTS         12           14           16           0           0
BACKLOG                   0            0            0           0           0
GROSS REQUIREMENTS       12           14           16           0           0
STOCK ON HAND            38           26          112          96           0
MPS                       0          100            0           0           0


                    *******  RECEIPT LIST REPORT  *******

                    -----------------------------------
                    WEEK NO.     QUANTITY     SCRAP
                                  (UNITS)     (UNITS)

                    -----------------------------------
                       44          100         5.00
                       50          100         5.00
```

3.4.3 Explanation of Terminologies

The terminologies used in the reports are explained as follows:

Part Number

- A unique number or alphanumeric value which identifies the item.

Description

- Name of the end item.

Make/Buy

- Refers to whether the end item is manufactured in-house or purchased.

A/B/C

- The ABC classification is based on the Pareto curve. Class A items are the few items which account for 80% of the total inventory value. Class C items are 80% of the items which account for a few per cent of the total inventory value. Class B items are those items which fall in between the above two classes and account for the balance of the total inventory value.

Lead Time Code

- Defined as the time between the receipt of an order to its issue onto the shop floor for manufacture. On the basis of duration, lead time is divided into three classifications; long denoted by 1, medium denoted by 2 and short denoted by 3. Management decides what duration is considered as long, medium and short based on subjective judgement and experience.

Manufacturing Lead Time

- Defined as the time between the issue of the manufacturing order onto the shop floor and its completion.

Job Lot Size

- A quantity to be produced on each replenishment cycle. The quantity is determined by balancing the operating expense of setting up and following the order against the capital investment in the working stock that results from ordering more than enough for the current consumption.

Purchase Lead Time

- Defined as the time between the issue of the purchase order and the receipt of the goods.

Economic Order Quantity

- A quantity to be ordered on each replenishment cycle. The lot quantity is determined by balancing the operating expense of raising the order and following the order against the capital investment in the working stock that results from ordering more than enough for the current consumption.

Reorder Level

- The stock level at which a replenishment is made. The replenishment is equal to the job lot size for manufactured items and equal to the economic order quantity for purchased items.

Minimum Quantity

- Defined as the minimum job lot size which can be produced economically or the minimum purchase order quantity as stipulated by the supplier.

Maximum Quantity

- There could be a constraint such as storage space which puts a limit to the production or order size.

Scrap

- A percentage factor applied to a job lot to account for scrap due to unsatisfactory product quality.

Horizon

- The number of periods through which requirements are planned or forecast.

Gross Forecast

- Forecasted demand results obtained from the Forecasting Model.

Bookings

- Orders already confirmed by the customers.

Net Forecast

- Defined as the difference between the gross forecast and bookings.

Net Requirements

- If gross forecast is greater than bookings, net requirements are equal to gross forecast. On the contrary, net requirements are equal to bookings.

Backlog

- Orders confirmed and promised to customers but the delivery date is missed. Priority is given to the backorder on completion of the next batch of end items.

Gross Requirements

- Equals the sum of the net requirements and backlog.

Stock On Hand

- The quantity of stock of a product that is available for sale, less any reservations or commitments for current shipment.

3.4.4 Discussion of Results

Table 3.3 shows the Long Term Master Production Schedule for Dock Leveller Model M68 which has a planning horizon of twelve periods. The period here is defined as six months. The user may define any duration for "period" which suits the purpose of the situation. The economic order quantity is fifty units while the reorder level is ten units for this particular product.

In this case, the Master Production Schedule lots are created for each of the twelve periods because the stock on hand is less than the reorder level in each occasion. The Master Production Schedule lot is created in multiplications of the economic order quantity. For example, in the thirteenth period, the Master Production Schedule lot is three times the economic order quantity.

The twenty-fifth period is the first period outside the planning horizon period. The stock on hand carried forward is nine. The rest are indicated by zero because no computation has occured beyond the planning horizon.

If the booking is greater than the gross forecast as indicated in the fifteenth period, the booking is used for computing the Master Production Schedule lot, instead of the gross forecast.

Table 3.6 shows the Short Term Master Production Schedule for Dock Leveller Model M610.

The planning horizon is eight weeks. The Master Production Schedule lot is created during the forty-fourth week. This Master Production Schedule lot is equal to the economic order quantity. The next Master Production Schedule lot is not created until week number fifty.

Tables 3.4 and 3.5 become self explanatory. These tests reveal the different structure of the reports and how the model handles different input information accurately and efficiently.

4. RESOURCE REQUIREMENTS PLANNING (RRP) MODEL

4.1 Resource Requirements Planning

Capacity planning and control is addressed to three different time horizons which correspond to three major decision areas for material management. These three time horizons for capacity planning and control are long range, medium range and short range. In the long range, capacity planning and control is concerned with decisions affecting resources that take long periods of time to acquire or dispose of and always require top management approval. These resources include land, facilities, machines, equipment and workforce as they relate to capacity to meet production objectives as dictated by the Long Term Master Production Schedule.

The term used in connection with long range planning of capacity at the Long Term Master Production Schedule level is Resource Requirements Planning or Rough-Cut Capacity Planning. The objective of Resource Requirements Planning is to assess any imbalance between the planned factors that affect capacity and the Long Term Master Production Schedule.

4.1.1 Establishment of a Resource Requirements Plan

The task of carrying out simulation experiments employing the Resource Requirements Planning Model is the responsibility of the Master Scheduler.

In the long term, it is only possible to approximate the capacity required from the plant work centers and vendors. It cannot be precise as the process relies on long term forecasts. The steps involved in organizing a Resource Requirements Plan are as follows:

1. The first round is conducted to produce results which are used to aid long term planning. The output of the Long Term Master Production Schedule forms one of the prime inputs into the Resource Requirements Planning Model. The other major input is the load profile of the end items concerned. The Resource Requirements Planning Model produces the Long Term Work Center Load Report and the Overload Report. The Long Term Work Center Load Report together with the Overload Report highlight whether the company has the available capacity to meet the Long Term Master Production Schedule.
2. The reports produced by the Master Production Schedule and Resource Requirements Planning Models are circulated to the interfacing departments for approval. Once approved, the Long Term Master Production Schedule is fixed for six months or for a period deemed appropriate by the senior managers. If the contrary happens, the revised Long Term Master Production Schedule is

resimulated through the Resource Requirements Planning Model. The process is repeated until a realistic Master Production Schedule is achieved.

3. The next step involves usage of the Capacity Requirements Planning Model. Detail coverage of the application of the Capacity Requirements Planning Model is given in chapter 5.

The Master Scheduler should be aware that it is not necessary to include all the departments or machine groups or machines on the shop floor during the simulation experiment. If the Master Scheduler knows from past experience which is/are the bottleneck department(s) or machine group(s) or machines, it is reasonable to simulate only for these department(s) or machine group(s) or machine(s).

4.1.1.1 Suggested Solutions For Long Term Capacity Planning

In the event of insufficient capacity, there are a number of ways of overcoming the problem, such as:

1. adding additional facilities,
2. raising labour performance,
3. working overtime,
4. adding additional shifts, and
5. subcontracting to suitable subcontractors.

These and other alternatives need to be explored and an effective solution implemented.

On the other hand, if the available capacity exceeds the required capacity, management may fill the "spare" capacity by one of the following methods:

1. increasing the Long Term Master Production Schedule,
2. reducing the capacity available by selling redundant machines and trimmimg the labour force, and
3. subcontracting from suitable suppliers.

4.2 The Resource Requirements Planning Computer Program

The model design is developed on the basis of the following rules:

1. The capacity available from a department only includes the normal operating capacity of the department. It must not include overtime or any other abnormal operating conditions.
2. The company can only sub-divide its production facility up to a maximum of twenty departments. Each department can only accommodate a maximum of thirty machines. This limitation is necessary in order that the core memory capacity of the present basic IBM personal computer system is not exceeded. It can be increased when the core and external memory capacities of the machine are expanded to one and five megabytes respectively. (The machine limitations are thoroughly discussed in section 6.2.)

4.2.1 Model Algorithm

The flow diagram of the Resource Requirements Planning Model is shown in Figure 4.1.

The variables used in the flow diagram are defined in Appendix A.

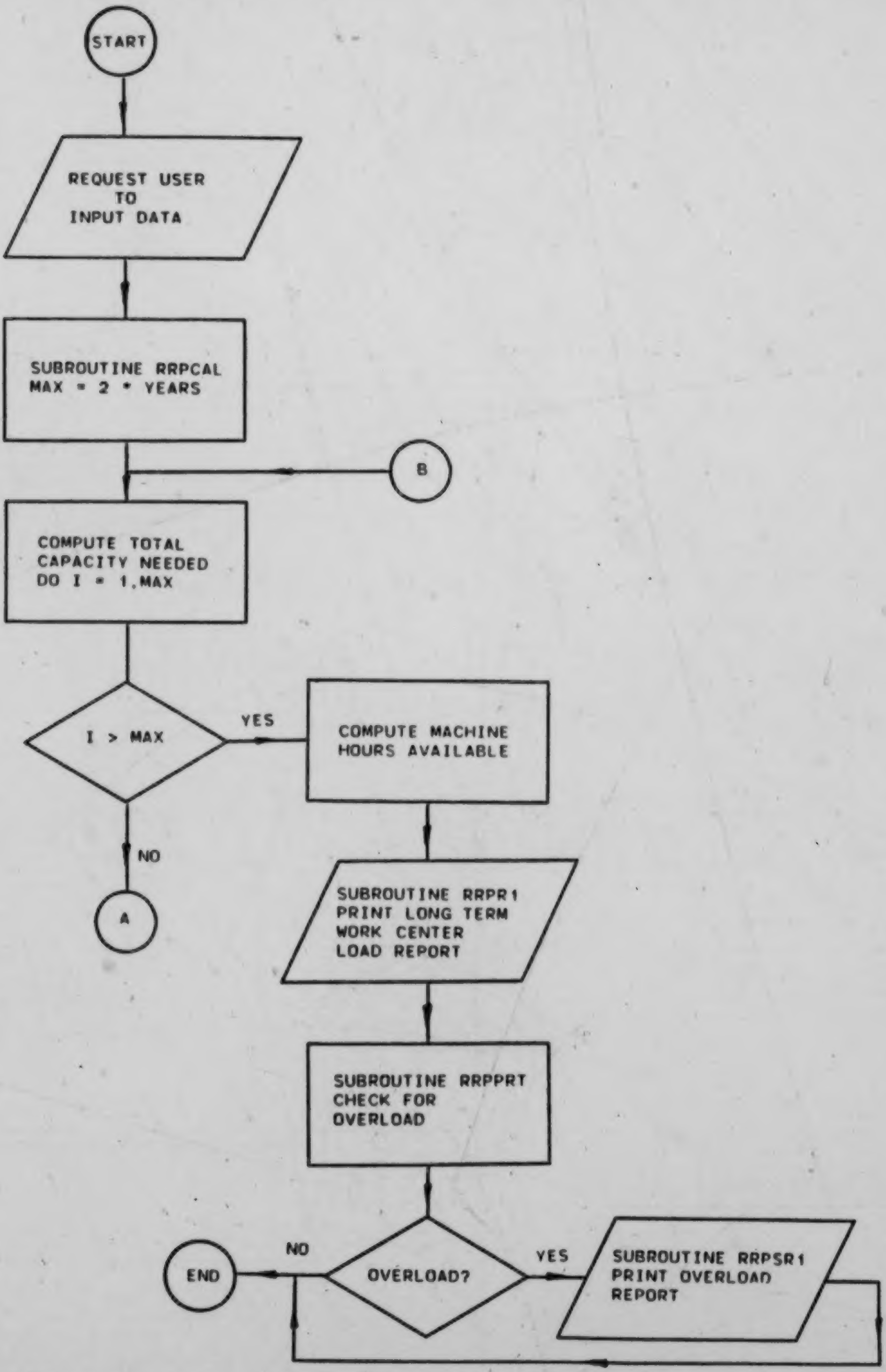


Figure 4.1 Resource Requirements Planning Model Flow Chart

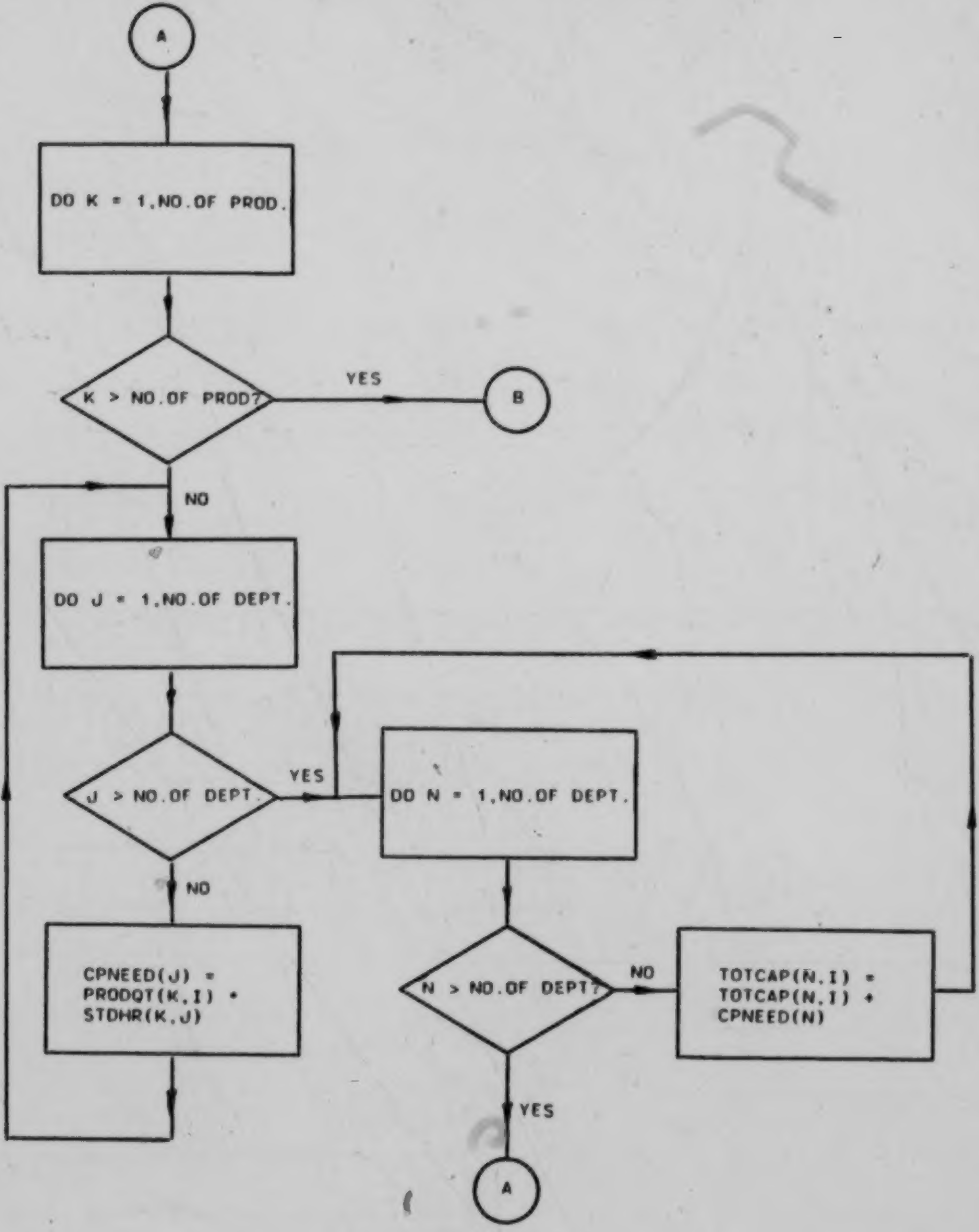


Figure 4.1 Continued

The algorithmic flow of the Resource Requirements Planning Model is explained below:

1. The user is required to key in data as requested by the "prompts". The types of data required are listed and explained in section 4.4.
2. The main program calls the subroutine RRPCAL to manipulate the input data and make the necessary calculations.
3. The main program then transfers the calculated data to the subroutines RRPR1 and RRPSR1. These routines rearrange the data and formats the Long Term Work Center Load Report and the Overload Report respectively. The reports are then printed on the line printer.

4.2.2 Input Data Format

The Resource Requirements Planning Model is partly interactive and partly non-interactive.

The production quantity, capacity availability and capacity requirement data are input on a "batch" mode basis. It is more efficient to input a large amount of information using the "batch" mode of data entry.

4.2.2.1 Production Quantity File

Table 4.1 shows an example of a production quantity file.

Table 4.1

Production Quantity File Format Example

PRODCD (10 alpha-numeric characters)

Example: DLM68

PRODQT (5 digits)

Example:

```
00150 00150 00100 00150 00100 00150 00150 00100
```

The variables are defined as follows:

PRODCD - Product code.

PRODQT - Production quantity.

PRODCD is typed in on the first line. PRODQT is entered on the next line and each PRODQT is separated by a space. The above two variables are repeated for the number of products required for processing.

4.2.2.2 Capacity Available File

Table 4.2 shows an example of a capacity available file.

Table 4.2

Capacity Available File Format Example

NDMC (4 digits)

Example: 0009

DCODE (4 alpha)	MCAP (6 digits)	MORD (1 alpha)
Example:	Example:	Example:
DMS	000016	M
DMP	000024	M
DMPB	000024	M
DP	000008	D

The variables are defined as follows:

NDMC - Total number of departments, machine groups and machines.

DCODE - Department or machine group or machine code.

DMP - Group of presses in the metal working department.

DMS - Group of shears in the metal working department.

DMPB - Group of press brakes in the metal working department.

DP - Painting department.

MCAP - Capacity available in standard hours per day.

MORD - Machine group or machine or department identification.

M - Machine.

D - Department.

NDMC is inserted on the first line. It is then followed by DCODE, MCAP and MORD, each separated by a space on the second line. DCODE, MCAP and MORD are repeated NDMC times.

4.2.2.3 Capacity Required File

Table 4.3 shows an example of a capacity required file.

Table 4.3

Capacity Required File Format Example

PRODCD (10 alpha-numeric characters)

Example: DLM68

DCODE (4 alpha)	CREQ (4 digits)
Example:	Example:
DMS	0012
DMP	0003
DMPB	0015

The variables are defined as follows:

PRODCD - Product code.

DCODE - Department or machine group or machine code.

DMS - Group of shears in the metal working department.

DMP - Group of presses in the metal working department.

DMPB - Group of press brakes in the metal working department.

CREQ - Capacity required for manufacturing the product in standard hours.

PRODCD is keyed in on the first line and indented one space to the right. It is then followed by DCODE and CREQ, each separated by a space on the second line. DCODE and CREQ are repeated NDMC times, after which all of the preceding information is repeated for all the products.

4.2.2.4 Resource Definition

The term resource in this context refers to physical resources such as machines and people. The shop floor of Argo Engineering Limited is classified into six departments. Each department has a variety of machines. However, within each variety of machines, there are a few machines which have common characteristics. These machines may be grouped together for the purpose of simulating through the Resource Requirements Planning Model. Machines which cannot be aggregated may be simulated individually. In cases where a department accommodates only one type of machine, the department may be used to represent a single physical resource.

To illustrate the above, a sample of the machines existing on the shop floor of Argo Engineering Limited are aggregated as depicted in Table 4.4.

Table 4.4

Department-Machine Group Code

No.	Machine	Dept. Code	Machine Group Code
1.	Shear - Bisco Model 10	DM	DMS
2.	Shear - Loblick Special	DM	DMS
3.	Punch - Brown Bogg	DM	DMP
4.	Punch - Brown Bogg	DM	DMP
5.	Punch - Loblick Special	DM	DMP
6.	Press Brake	DM	DMPB
7.	Press Brake	DM	DMPB
8.	Press Brake	DM	DMPB
9.	MIG Welder	DW	DWM
10.	MIG Welder	DW	DWM
11.	MIG Welder	DW	DWM
12.	Arc Welder	DW	DWA
13.	Arc Welder	DW	DWA
14.	Lathe - Grazlano	DS	DSL
15.	Lathe - Economatic	DS	DSL
16.	Drill - Modigs	DS	DSD
17.	Drill - Arboga	DS	DSD
18.	Grinder - Metabo	DS	DSG
19.	Grinder - Metabo	DS	DSG
20.	Painting System	DP	None

The Resource Requirements Planning Model is designed to accept departmental and machine group codes with a maximum of two and four characters respectively. The above coding system is proposed for the following reasons:

1. it is simple and satisfies the prerequisite of the Resource Requirements Planning Model;
2. an individual can understand the coding system almost immediately.

4.2.2.5 Load Profile Definition

The procedures for computing the load profile is described below:

1. The Bill of Materials for the product whose load profile is to be computed is identified.
2. The production routing and the corresponding time study data are identified for each item which makes up the end product.
3. The standard time for all the raw materials, sub-assemblies and assemblies which utilize the facility of a particular department or machine group or machine as appropriate is added. This is done by referring to the production routes and cumulatively totalling the corresponding standard time by department or machine group or machine as appropriate.
4. The load profile of the end item concerned is thus defined for each department or machine group or machine.

Argo Engineering Limited at present does not keep time study data. It is recommended that the company launch a program for collecting and later updating time study records. A more elaborate discussion of record keeping and record integrity is presented in chapter 7.

4.3 Editing of the Data Files

The permanent files are edited by using the Disk Operating System (DOS). The Disk Operating System diskette is inserted into drive A and the data file into drive B.

To enter edit mode in order to edit the data file, the command **A:EDLIN data file name** is keyed in. When the editing is completed, the edited file is saved by keying in the command **E** . However, the old file is still retained as a back-up copy. Detailed instructions are given in the IBM personal computer manual - Disk Operating System.

4.4 Testing the Model

The department or machine groups indicated are "real life" data collected from Argo Engineering Limited. However, the capacity required by each end product is hypothetical.

4.4.1 Batch Mode Input Data

The input data for the production quantity, capacity available and capacity required data files are entered by utilizing the editing facility provided by the Disk

Operating System (DOS).

The respective input data are depicted in Tables 4.5, 4.6 and 4.7.

Table 4.5

Production Quantity File Input Data

```
0002
DLM68
00150 00150 00100 00150 00100 00150 00150 00100
DLM610
00100 00150 00100 00100 00150 00150 00100 00100
```

Table 4.6

Capacity Available File Input Data

```
0009
DMS  000016 M
DMP  000024 M
DMPB 000024 M
DWM  000024 M
DWA  000016 M
DSL  000016 M
DSD  000016 M
DSG  000016 M
DP   000008 D
```

Table 4.7

Capacity Required File Input Data

```
DLM68
DMS  0012
DMP  0003
DMPB 0015
DWM  0008
DWA  0007
DSL  0010
DSD  0004
DSG  0009
DP   0008
DLM610
DMS  0011
DMP  0003
DMPB 0010
DWM  0009
DWA  0005
DSL  0007
DSD  0006
DSG  0012
DP   0007
```

4.4.2 Interactive Input Data Format

The Resource Requirements Planning Model is called into interactive mode by keying in the file name **RRPM.**

The terminal session is illustrated as follows:

```
****************************************

* RESOURCE REQUIREMENTS PLANNING MODEL *

****************************************

Enter today's date:

08/21/82

Enter number of years to be processed (2 digits):

04

Enter beginning year (4 digits):
```

```
1982
**** PROCESSING ......
```

4.4.3 Output Data Format

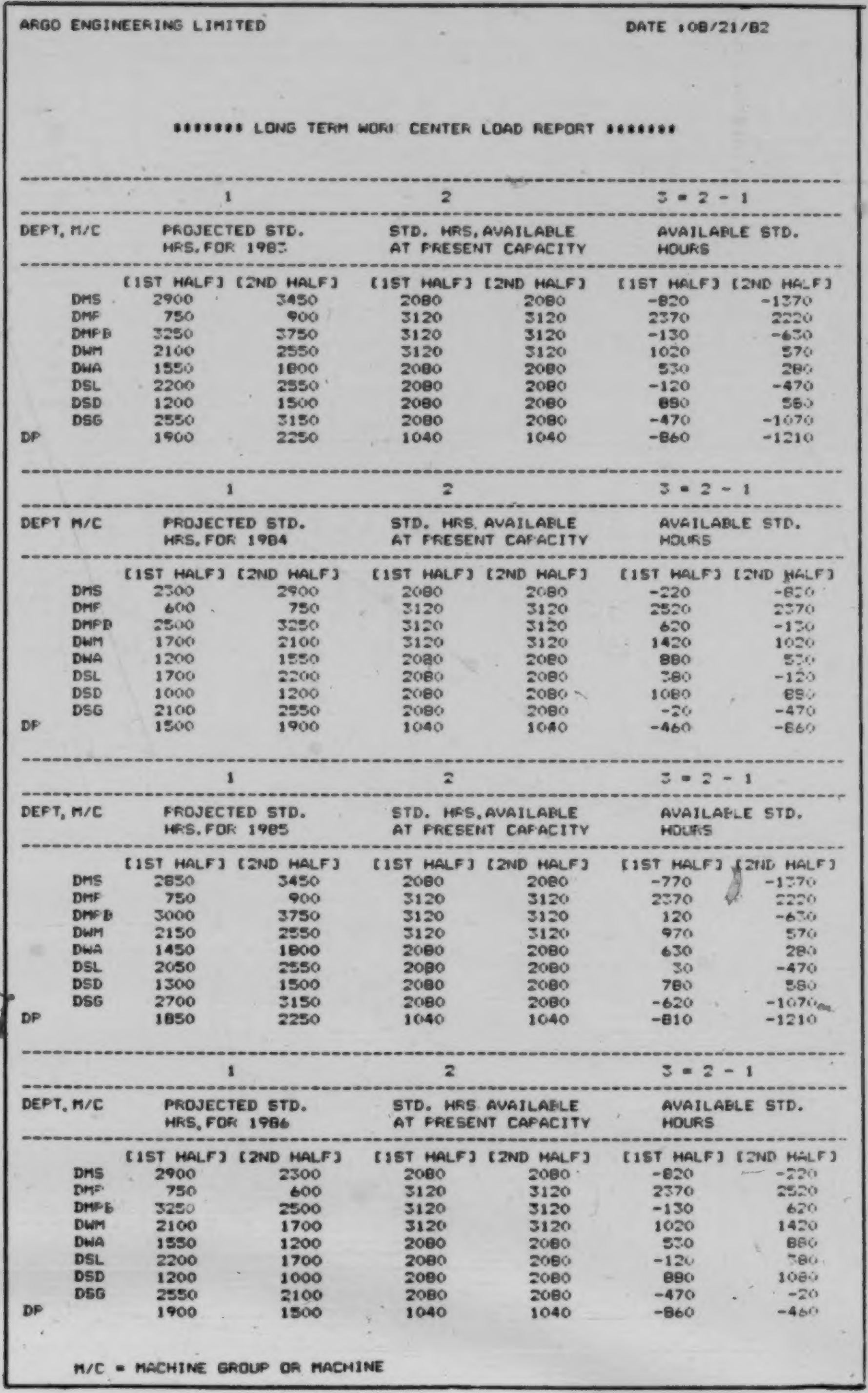
The output data consists of a Long Term Work Center Load Report and an Overload Report. The latter will not be printed if there are no overloads.

The results of the above terminal session is illustrated in Tables 4.8 and 4.9. Table 4.8 shows the capacity available and capacity needed from each department for a four year projection. Each year is sub-divided into two halves as long term planning is reviewed every six months. The third row shows the balance of the capacity available. The negative sign implies an overload.

The prime purpose of the Long Term Work Center Load Report is to aid management in making long range decisions and to justify the decision taken. The decision may be the alteration of the Long Term Master Production Schedule3 or may result in purchase of additional machines and extending the existing manufacturing facilities.

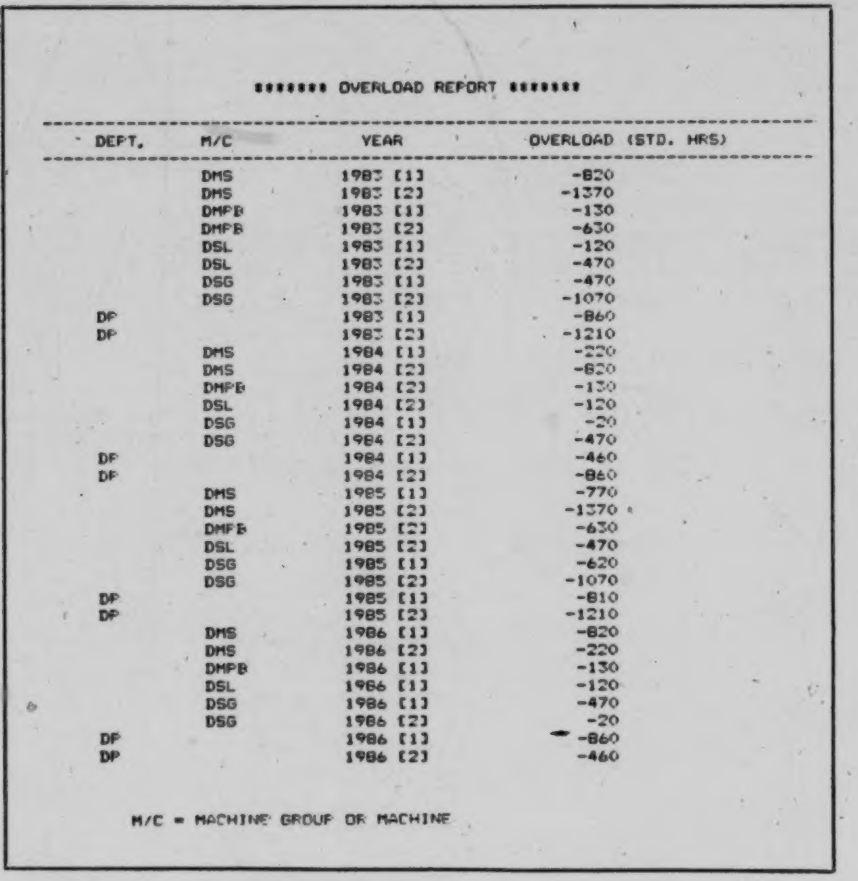
The purpose of the Overload report is to substantiate the Long Term Work Center Load Report. The Overload Report summarizes the situations which have inadequate capacity.

Table 4.8 Long Term Work Center Load Report 1



```
ARGO ENGINEERING LIMITED                                    DATE :08/21/82



              ******* LONG TERM WORK CENTER LOAD REPORT *******

------------------------------------------------------------------------------
                   1                      2                      3 = 2 - 1
------------------------------------------------------------------------------
DEPT, M/C       PROJECTED STD.        STD. HRS,AVAILABLE       AVAILABLE STD.
                HRS.FOR 1983          AT PRESENT CAPACITY      HOURS
------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]
       DMS       2900       3450        2080       2080        -820      -1370
       DMF        750        900        3120       3120        2370       2220
       DMPB      3250       3750        3120       3120        -130       -630
       DWM       2100       2550        3120       3120        1020        570
       DWA       1550       1800        2080       2080         530        280
       DSL       2200       2550        2080       2080        -120       -470
       DSD       1200       1500        2080       2080         880        560
       DSG       2550       3150        2080       2080        -470      -1070
DP               1900       2250        1040       1040        -860      -1210

------------------------------------------------------------------------------
                   1                      2                      3 = 2 - 1
------------------------------------------------------------------------------
DEPT M/C        PROJECTED STD.        STD. HRS AVAILABLE       AVAILABLE STD.
                HRS.FOR 1984          AT PRESENT CAPACITY      HOURS
------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]
       DMS       2300       2900        2080       2080        -220       -820
       DMF        600        750        3120       3120        2520       2370
       DMPB      2500       3250        3120       3120         620       -130
       DWM       1700       2100        3120       3120        1420       1020
       DWA       1200       1550        2080       2080         880        530
       DSL       1700       2200        2080       2080         380       -120
       DSD       1000       1200        2080       2080        1080        880
       DSG       2100       2550        2080       2080         -20       -470
DP               1500       1900        1040       1040        -460       -860

------------------------------------------------------------------------------
                   1                      2                      3 = 2 - 1
------------------------------------------------------------------------------
DEPT, M/C       PROJECTED STD.        STD. HRS,AVAILABLE       AVAILABLE STD.
                HRS.FOR 1985          AT PRESENT CAPACITY      HOURS
------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]
       DMS       2850       3450        2080       2080        -770      -1370
       DMF        750        900        3120       3120        2370       2220
       DMPB      3000       3750        3120       3120         120       -630
       DWM       2150       2550        3120       3120         970        570
       DWA       1450       1800        2080       2080         630        280
       DSL       2050       2550        2080       2080          30       -470
       DSD       1300       1500        2080       2080         780        580
       DSG       2700       3150        2080       2080        -620      -1070
DP               1850       2250        1040       1040        -810      -1210

------------------------------------------------------------------------------
                   1                      2                      3 = 2 - 1
------------------------------------------------------------------------------
DEPT, M/C       PROJECTED STD.        STD. HRS AVAILABLE       AVAILABLE STD.
                HRS, FOR 1986         AT PRESENT CAPACITY      HOURS
------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]  [1ST HALF] [2ND HALF]
       DMS       2900       2300        2080       2080        -820       -220
       DMF        750        600        3120       3120        2370       2520
       DMPB      3250       2500        3120       3120        -130        620
       DWM       2100       1700        3120       3120        1020       1420
       DWA       1550       1200        2080       2080         530        880
       DSL       2200       1700        2080       2080        -120        380
       DSD       1200       1000        2080       2080         880       1080
       DSG       2550       2100        2080       2080        -470        -20
DP               1900       1500        1040       1040        -860       -460


       M/C = MACHINE GROUP OR MACHINE
```

Table 4.9 Overload Report 1



```
                    ******* OVERLOAD REPORT *******

-------------------------------------------------------------------------
  DEPT.     M/C              YEAR              OVERLOAD (STD. HRS)
-------------------------------------------------------------------------
            DMS            1983 [1]                  -820
            DMS            1983 [2]                 -1370
            DMPB           1983 [1]                  -130
            DMPB           1983 [2]                  -630
            DSL            1983 [1]                  -120
            DSL            1983 [2]                  -470
            DSG            1983 [1]                  -470
            DSG            1983 [2]                 -1070
  DP                       1983 [1]                  -860
  DP                       1983 [2]                 -1210
            DMS            1984 [1]                  -220
            DMS            1984 [2]                  -820
            DMPB           1984 [2]                  -130
            DSL            1984 [2]                  -120
            DSG            1984 [1]                   -20
            DSG            1984 [2]                  -470
  DP                       1984 [1]                  -460
  DP                       1984 [2]                  -860
            DMS            1985 [1]                  -770
            DMS            1985 [2]                 -1370
            DMPB           1985 [2]                  -630
            DSL            1985 [2]                  -470
            DSG            1985 [1]                  -620
            DSG            1985 [2]                 -1070
  DP                       1985 [1]                  -810
  DP                       1985 [2]                 -1210
            DMS            1986 [1]                  -820
            DMS            1986 [2]                  -220
            DMPB           1986 [1]                  -130
            DSL            1986 [1]                  -120
            DSG            1986 [1]                  -470
            DSG            1986 [2]                   -20
  DP                       1986 [1]                  -860
  DP                       1986 [2]                  -460


      M/C = MACHINE GROUP OR MACHINE
```

4.4.4 Discussion of Results

Table 4.9 shows that the machine groups DMS (shear) and DSD (drill) and the department DP (painting) are overloaded for all the years projected. Machine groups DMP (press), DWM (MIG welder) and DWA (arc welder) are underloaded for all the years projected. Machine groups DMPB (press brake), DSL (lathe) and DSD (drill) have variations of overload and underload. The exact amount of overload and underload for each machine group or department for each period is given in Table 4.8.

The Overload Report shown in Table 4.9 indicates thirty-four overload situations. It also provides information as to *"how much"*, *"where"* and *"when"* the overloads occured.

4.4.5 Sensitivity Analysis

The capacity availability was increased as an attempt to overcome the problem. The capacity available from each machine group or department were altered as follows:

1. machine group DMS (shear) increased from sixteen to twenty-four standard hours,
2. machine group DMP (press) was unaltered,
3. machine group DMPB (press brake) increased from twenty-four to thirty-two standard hours,
4. machine group DWM (MIG welder) was unaltered,
5. machine group DWA (arc welder) was unaltered,
6. machine group DSL (lathe) was unaltered,

7. machine group DSD (drill) was unaltered,
8. machine group DSG (grinder) was increased from sixteen to twenty-four standard hours, and
9. department DP (painting) was increased from eight to sixteen standard hours.

The capacity available file was edited by utilizing the editing facility provided by the Disk Operating System (DOS). The edited data is depicted in Table 4.10.

Table 4.10

Edited Capacity Available File

```
0009
DMS  000024 M
DMP  000024 M
DMPB 000032 M
DWM  000024 M
DWA  000016 M
DSL  000016 M
DSD  000016 M
DSG  000024 M
DP   000016 D
```

The effect of this action is to reduce the overload situations to eleven ocassions. The overload situations which have been removed are:

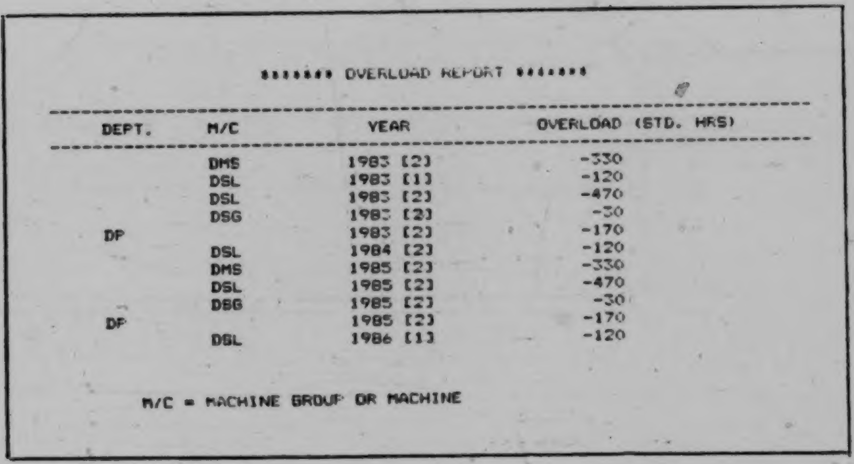
No.	Dept.	Machine Group	Period
1.		DMS	1982[1],
2.		DMS	1982[2],
3.		DMS	1983[1],
4.		DMS	1983[2],
5.		DMS	1984[1],
6.		DMS	1984[2],
7.		DMS	1985[1],
8.		DMS	1986[1],
9.		DMS	1986[2].
10.		DSG	1984[1],
11.		DSG	1984[2],
12.	DP		1984[1],
13.	DP		1984[2],
14.		DMS	1985[1],
15.		DMPB	1985[2],
16.		DSG	1985[1],
17.	DP		1985[1],
18.		DMS	1986[1],
19.		DMS	1986[2],
20.		DSG	1986[1],
21.		DSG	1986[2],
22.	DP		1986[1], and
23.	DP		1986[2].

"[1]" represents the first half of the year while "[2]" represents the second half. The results are depicted in Tables 4.11 and 4.12.

Table 4.11 Long Term Work Center Load Report 2

```
ARGO ENGINEERING LIMITED                                        DATE :08/21/82


                  ******* LONG TERM WORK CENTER LOAD REPORT *******

------------------------------------------------------------------------------------
                       1                       2                      3 = 2 - 1
------------------------------------------------------------------------------------
DEPT. M/C      PROJECTED STD.           STD. HRS.AVAILABLE          AVAILABLE STD.
               HRS.FOR 1983             AT PRESENT CAPACITY         HOURS
------------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]
      DMS       2900        3450          3120       3120          220       -330
      DMP        750         900          3120       3120         2370       2220
      DMPB      3250        3750          4160       4160          910        410
      DWM       2100        2550          3120       3120         1020        570
      DWA       1550        1800          2080       2080          530        280
      DSL       2200        2550          2080       2080         -120       -470
      DSD       1200        1500          2080       2080          880        580
      DSG       2550        3150          3120       3120          570        -30
DP              1900        2250          2080       2080          180       -170

------------------------------------------------------------------------------------
                       1                       2                      3 = 2 - 1
------------------------------------------------------------------------------------
DEPT. M/C      PROJECTED STD.           STD. HRS.AVAILABLE          AVAILABLE STD.
               HRS.FOR 1984             AT PRESENT CAPACITY         HOURS
------------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]
      DMS       2300        2900          3120       3120          820        220
      DMP        600         750          3120       3120         2520       2370
      DMPB      2500        3250          4160       4160         1660        910
      DWM       1700        2100          3120       3120         1420       1020
      DWA       1200        1550          2080       2080          880        530
      DSL       1700        2200          2080       2080          380       -120
      DSD       1000        1200          2080       2080         1080        880
      DSG       2100        2550          3120       3120         1020        570
DP              1500        1900          2080       2080          580        180

------------------------------------------------------------------------------------
                       1                       2                      3 = 2 - 1
------------------------------------------------------------------------------------
DEPT. M/C      PROJECTED STD.           STD. HRS.AVAILABLE          AVAILABLE STD.
               HRS.FOR 1985             AT PRESENT CAPACITY         HOURS
------------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]
      DMS       2850        3450          3120       3120          270       -330
      DMP        750         900          3120       3120         2370       2220
      DMPB      3000        3750          4160       4160         1160        410
      DWM       2150        2550          3120       3120          970        570
      DWA       1450        1800          2080       2080          630        280
      DSL       2050        2550          2080       2080           30       -470
      DSD       1300        1500          2080       2080          780        580
      DSG       2700        3150          3120       3120          420        -30
DP              1850        2250          2080       2080          230       -170

------------------------------------------------------------------------------------
                       1                       2                      3 = 2 - 1
------------------------------------------------------------------------------------
DEPT. M/C      PROJECTED STD.           STD. HRS.AVAILABLE          AVAILABLE STD.
               HRS.FOR 1986             AT PRESENT CAPACITY         HOURS
------------------------------------------------------------------------------------
              [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]    [1ST HALF] [2ND HALF]
      DMS       2900        2300          3120       3120          220        820
      DMP        750         600          3120       3120         2370       2520
      DMPB      3250        2500          4160       4160          910       1660
      DWM       2100        1700          3120       3120         1020       1420
      DWA       1550        1200          2080       2080          530        880
      DSL       2200        1700          2080       2080         -120        380
      DSD       1200        1000          2080       2080          880       1080
      DSG       2550        2100          3120       3120          570       1020
DP              1900        1500          2080       2080          180        580


      M/C = MACHINE GROUP OR MACHINE
```

Table 4.12 Overload Report 2



```
                    ******* OVERLOAD REPORT *******
------------------------------------------------------------------
   DEPT.     M/C          YEAR          OVERLOAD (STD. HRS)
------------------------------------------------------------------
             DMS        1983 [2]             -330
             DSL        1983 [1]             -120
             DSL        1983 [2]             -470
             DSG        1983 [2]              -30
   DP                   1983 [2]             -170
             DSL        1984 [2]             -120
             DMS        1985 [2]             -330
             DSL        1985 [2]             -470
             DSG        1985 [2]              -30
   DP                   1985 [2]             -170
             DSL        1986 [1]             -120


      M/C = MACHINE GROUP OR MACHINE
```

5. CAPACITY REQUIREMENTS PLANNING (CRP) MODEL

5.1 Capacity Requirements Planning

In the medium and short term, a detailed study is made of available and required capacity. In the medium and short range, the information is more certain. The required capacity can be computed directly from released and planned orders rather than using the approximation techniques in long range planning. As in long range planning, the objectives of medium and short term planning are to adjust factors that determine capacity until the required capacity computed from released and planned orders is in balance with the available capacity of the plant, work centers and vendors.

This area of capacity planning relates to the detailed Material Requirements Planning sub-system. The technique associated with medium and short term planning is referred to as Capacity Requirements Planning.

5.1.1 Establishment of a Capacity Requirements Plan

This section is a continuation of the long range capacity planning exercise described in the preceding chapter. What follows is a step-by-step procedure for setting up the Capacity Requirements Plan.

1. The Short Term Master Production Schedule is used to "drive" the Material Requirements Planning Model. The

start date and production quantity information are output from the Material Requirements Planning Model. These information, plus the production routing and time study data are input into the Capacity Requirements Planning Model.

2. The Capacity Requirements Planning Model produces the following reports:
    - Work Center Load Report,
    - Overload Report, and
    - Component Part Scheduling Report.

   Production planning and control studies the reports and decides if it is capable of resolving any impending capacity shortage. If production planning and control is capable of handling the problem, it is not necessary to raise the problem during the regular scheduled meetings. If the contrary happens, the team of senior managers are required to seek an acceptable solution to the problem. This may mean altering the Short Term Master Production Schedule, resimulating it through the Material Requirements Planning Model and subsequently the Capacity Requirements Planning Model until a satisfactory short term plan is achieved.
3. Once the short term plan is finalized, the Master Scheduler issues the Component Part Scheduling Report to the shop floor. The machine operators are required to follow the schedule indicated by the Component Part Scheduling Report.

4. The cycle is repeated once for the period as determined by the rate of change of the Short Term Master Production Schedule.

5.1.1.1 Suggested Solutions For Short Term Capacity Planning

If the required capacity is greater than the available capacity, management may take one or a combination of the following decisions:

1. working overtime,
2. subcontracting to suitable subcontractors,
3. transfer of operators to the bottleneck work centers, and
4. altering the Short Term Master Production Schedule.

On the other hand, if the capacity required is less than the available capacity, management has the option of taking one or a combination of the following actions:

1. reducing working hours,
2. releasing some orders early, and
3. laying off a portion of the workforce.

5.2 The Capacity Requirements Planning Computer Program

The model design is developed on the basis of the following rules:

1. Lead time and time study data are deterministic.
2. The maximum number of activities required to manufacture a component does not exceed fifty activities. This is done in order that the core memory capacity of the

present system is not exceeded. However, the number of activities can be increased when the core and external memory capacities are expanded to one and five megabytes respectively.

5.2.1 Model Algorithm

The algorithmic flow of the Capacity Requirements Planning Model is shown in Figure 5.1.

The variables used in the flow diagram are defined in Appendix A.

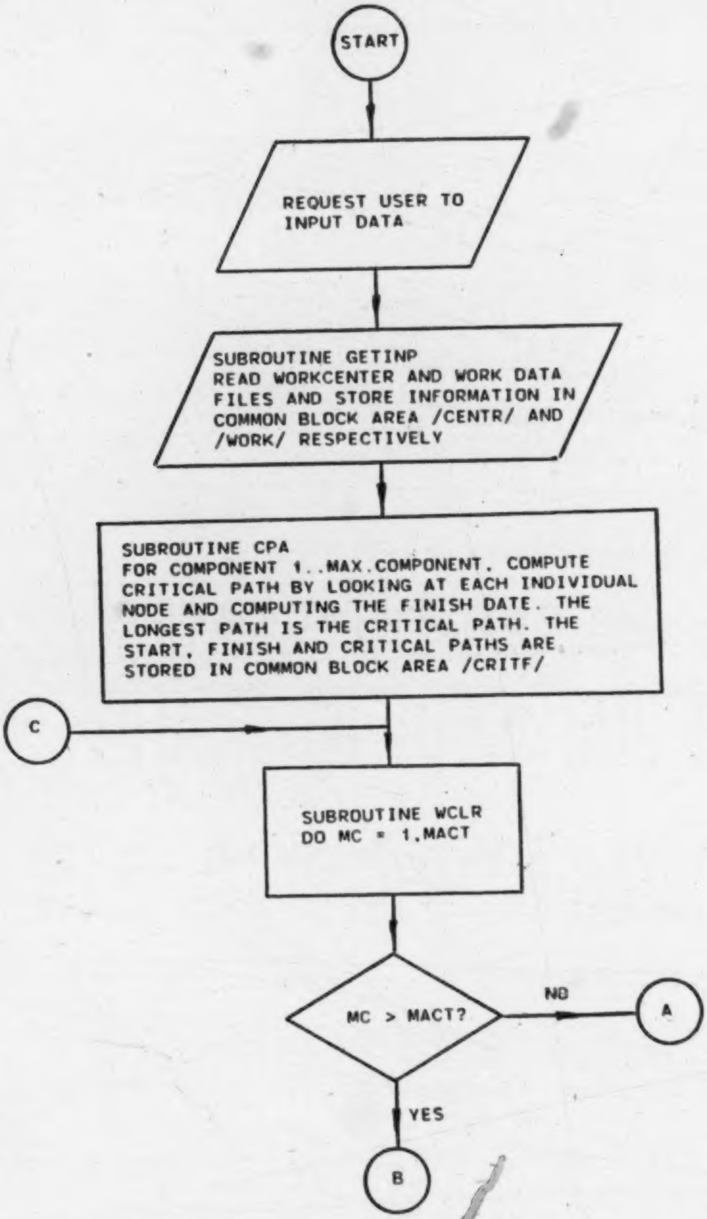

START
REQUEST USER TO INPUT DATA
SUBROUTINE GETINP
READ WORKCENTER AND WORK DATA FILES AND STORE INFORMATION IN COMMON BLOCK AREA /CENTR/ AND /WORK/ RESPECTIVELY
SUBROUTINE CPA
FOR COMPONENT 1..MAX.COMPONENT. COMPUTE CRITICAL PATH BY LOOKING AT EACH INDIVIDUAL NODE AND COMPUTING THE FINISH DATE. THE LONGEST PATH IS THE CRITICAL PATH. THE START, FINISH AND CRITICAL PATHS ARE STORED IN COMMON BLOCK AREA /CRITF/
C
SUBROUTINE WCLR
DO MC = 1,MACT
MC > MACT?
NO
A
YES
B

Figure 5.1 Capacity Requirements Planning Model Flow Chart

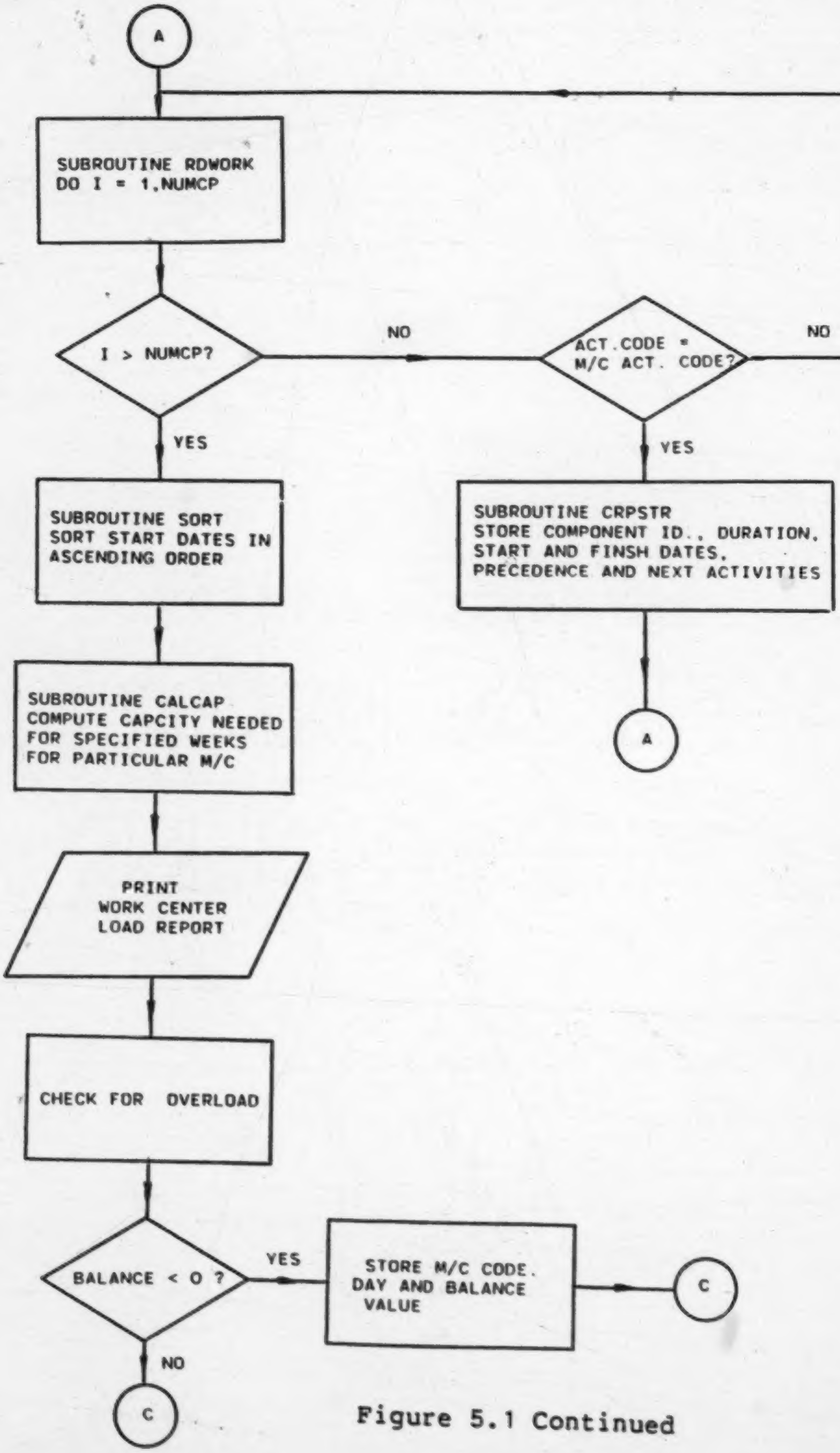


Figure 5.1 Continued

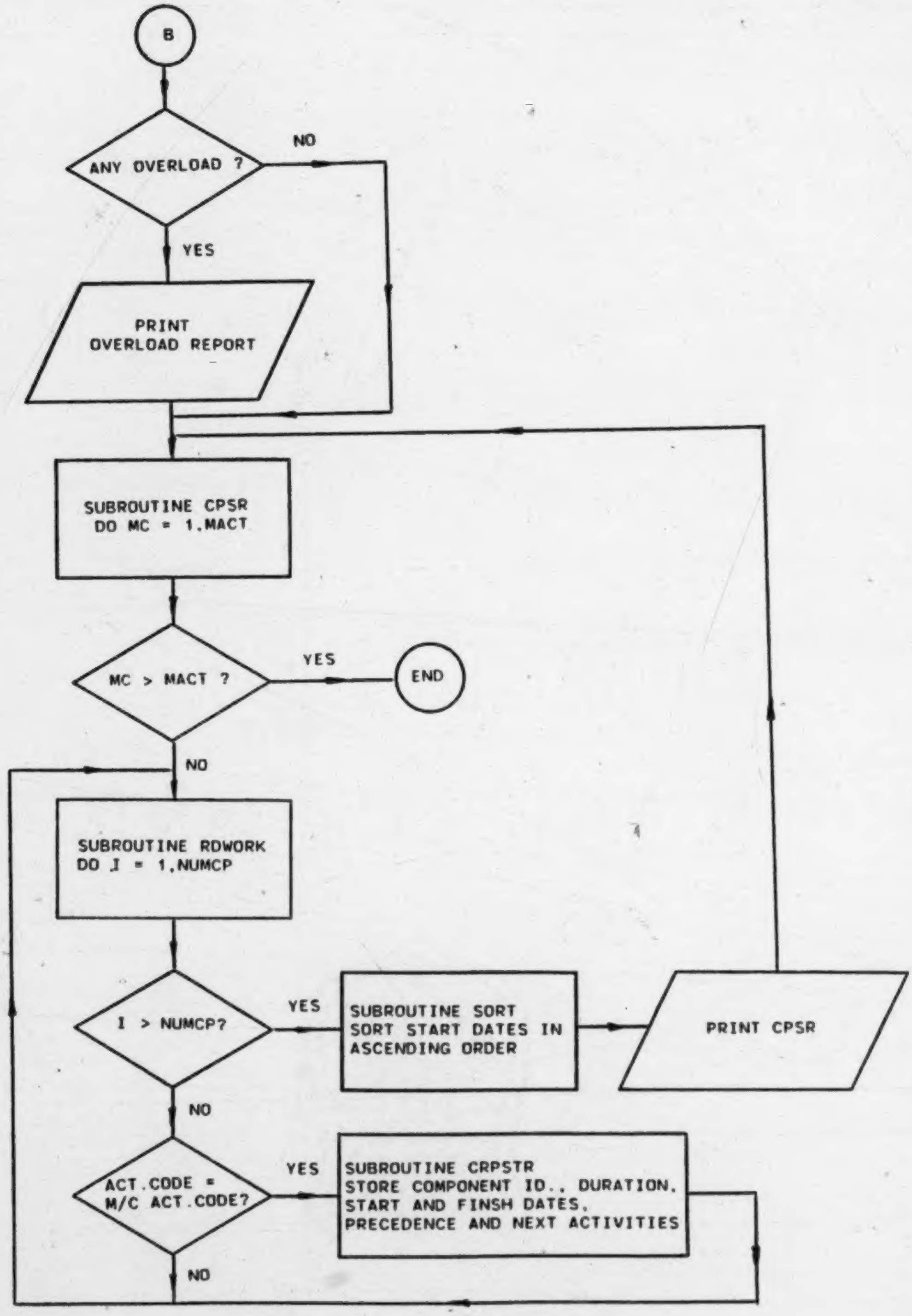

B
ANY OVERLOAD ?
NO
YES
PRINT OVERLOAD REPORT
SUBROUTINE CPSR DO MC = 1,MACT
MC > MACT ?
YES
END
NO
SUBROUTINE RDWORK DO I = 1,NUMCP
I > NUMCP?
YES
SUBROUTINE SORT SORT START DATES IN ASCENDING ORDER
PRINT CPSR
NO
ACT.CODE = M/C ACT.CODE?
YES
SUBROUTINE CRPSTR STORE COMPONENT ID., DURATION, START AND FINSH DATES, PRECEDENCE AND NEXT ACTIVITIES
NO

Figure 5.1 Continued

The algorithmic flow of the Capacity Requirements Planning Model is explained below:

1. The user is required to key in data as requested by the "prompts". The types of data required are listed and explained in section 5.3.
2. The main program calls the subroutine GETINP to open and read the data files; WORKFL and CENTREFL. Subroutine GETINP reads and stores the information in the common block area /WORK/ and /CENTR/ respectively.
3. The main program then calls subroutine CPA to compute the critical paths for all the components. This is accomplished by 'looking' at each individual node along the path and computing the finish date. The longest path is the critical path. The start, finish and critical path are stored in the common block area /CRITF/.
4. The main program then transfers control to the subroutine WCLR. This routine calls subroutine SORT to sort out the start dates in ascending order before printing the Work Center Load Report on the line printer.
5. The main program then calls subroutine OVERLR if there is any overload in the balance capacity.
6. The main program calls the subroutine CPSR to produce the Component Part Scheduling Report. Again, the subroutine SORT is called to sort out the start dates in ascending order before printing the report on the line printer.

5.2.2 Critical Path Analysis Technique

The Capacity Requirements Planning Model is based on the principle of Critical Path Analysis.

The heart of the Critical Path Analysis Technique is a network portrayal of the plan for carrying out a job. Such a network shows the precedence relationships of the elements of the job leading to the job's completion and is called an arrow diagram.

The development of the arrow diagram occurs in the planning phase of the job. Resources and times are neglected at this point. With respect to each element of the job, the following three questions are asked:

1. What immediately precedes this element?
2. What can be done concurrently?
3. What immediately follows this job?

With the answers to these questions, the engineer can draw an arrow diagram to describe a job. In an arrow diagram, the arrow represents the activities of the job under consideration and the node or event represents the precedence relationships between activities.

Figure 5.2 shows a job which has four activities 01, 02, 03 and 04. The relationships between these activities are:

1. activity 04 is started first;
2. activities 01 and 02 can be started simultaneously as soon as activity 04 is completed;
3. both activities 01 and 02 must be completed before

activity 03 may be started.

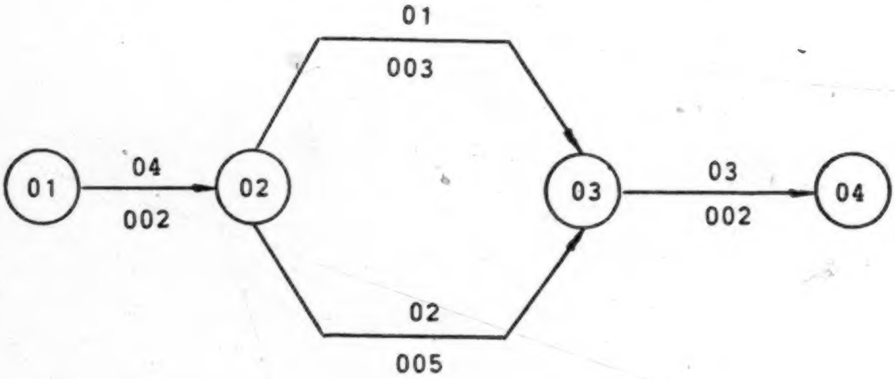


Figure 5.2 Activity Network

The next step is to allocate times and resources to each activity. The engineer then translates the information depicted by the arrow diagram into the format acceptable by the Capacity Requirements Planning Model. The format is explained in the section 5.2.3.1.

5.2.3 Input Data Format

The Capacity Requirements Planning Model is partly interactive and partly non-interactive. This is because it is required to process a large amount of information at frequent intervals. The time study, activity and work center data are therefore stored permanently in back-up files. The back-up copies are transferred to temporary files which are edited during each interval to suit the particular alteration.

When there is a revision in the time standard or a change of routing for a certain component, the user simply has to edit that particular piece of information in the permanent file and make the necessary changes. The procedures for editing the files have been briefly outlined in section 4.3.

5.2.3.1 Work File

The work file contains the information as indicated in Table 5.1. The variable names are defined as follows:

ACTCD - Activity code.
CPID - Component identification.
DESTND - Destination node.
DURATN - Duration for that activity code.
JNXT1 - First next activity.
JNXT2 - Second next activity.
JNXT3 - Third next activity.
JPRE1 - First precedence activity.
JPRE2 - Second precedence activity.
JPRE3 - Third precedence activity.
MAXACT - Maximum number of activities.
MAXND - Maximum nodes.
SND - Source node.

Table 5.1

Work File Format

CPID	MAXACT	MAXND
(10 alpha digits)	(2 digits)	(2 digits)

ACTCD	DURATN	SND	DESTND
(2 digits)	(3 digits)	(2 digits)	(2 digits)

JPRE1	JPRE2	JPRE3
(2 digits)	(2 digits)	(2 digits)

JNXT1	JNXT2	JNXT3
(2 digits)	(2 digits)	(2 digits)

The above table shows the information required for the processing of a single component. The same format is repeated for the next component and thereafter.

The CPID, MAXACT and MAXND are on the same line, each separated by a space. The ACTCD is indented one space from the left hand margin and all the variables following are separated from each other by a space. The JPRE1, JPRE2, JPRE3 and JNXT1, JNXT2, JNXT3 are indented two spaces from the left margin.

The example which follows will illustrate the format.

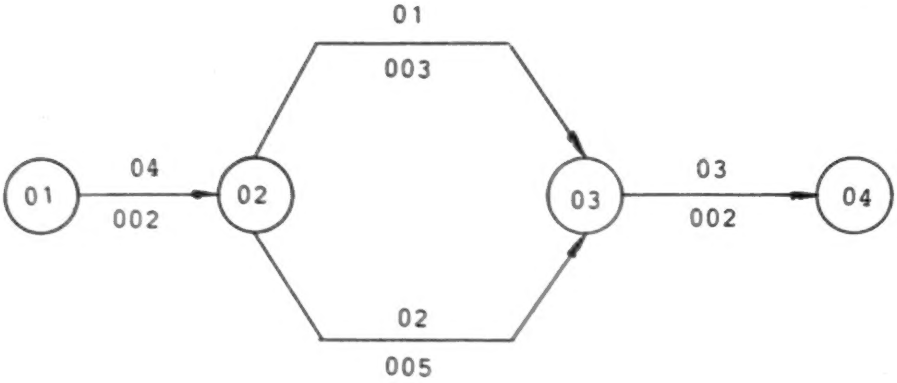


Figure 5.3 Arrow Diagram For Component DL3045

Table 5.2

Work File Format Example

```
DL3045    04 04
 04 002 01 02
  00 00 00
  01 02 00
 01 003 02 03
  04 00 00
  03 00 00
 02 005 02 03
  04 00 00
  03 00 00
 03 002 03 04
  01 02 00
  00 00 00
```

5.2.3.2 Work Center File

The work center file stores information with respect to the number of work centers, the work center code, the corresponding activity code and the corresponding capacity availability.

The user is required to follow exactly the format as illustrated in Table 5.3.

Table 5.3

Work Center File Format

MACT (3 digits)

Example: 003

MACTCD	MAXCAP	MCODE
(2 digits)	(3 digits)	(4 alpha-digits)
Example:	Example:	Example:
01	40	M520
02	35	C100
03	40	W330

The variables MACT, MACTCD, MAXCAP and MCODE are defined as follows:

MACT - Maximum number of machines in the file 'CENTREFL'.

MACTCD - Machine activity code.

MAXCAP - Maximum capacity.

MCODE - Machine code (Work center number).

MACT (which indicates the number of MACTCD or MAXCAP or MCODE to be entered) is typed in on the first line. MACTCD, MAXCAP and MCODE are entered MACT times. MACTCD is indented one space from the left hand margin and all the variables following are separated from each other by a space.

5.2.3.3 Activity Definition

In order for the computer to process the information contained in the work center and work files, the activity and work center must be coded so that they are meaningful to the computer.

The activity is coded by two digits. The two digit system for coding the activity allows efficient information processing and easy identification. Two digits are sufficient allowance for the addition of extra activities in the future. The maximum number of activities which can be coded by the two digit system is ninety-nine.

The corresponding work center for an activity is denoted by a character followed by three digits. The character identifies the location of the work center by department. The three digits give the exact location of the work center in a three dimensional space. The first digit represents the x-axis; the second digit represents the y-axis and the third digit represents the z-axis. The third digit is zero for the ground floor; one for the first floor; two for the second floor and so on.

To illustrate the coding system, it is necessary to code a number of the work centers existing on the shop floor of Argo Engineering Limited.

Table 5.4

Work Center and Activity Code

No.	Description	Workcenter Code	Activity
1	Shear-Bisco Cut Model 10	T330	07
2	Press Brake -70 tons	T380	02
3	Tig Welder	W550	03
4	Mig Welder	W590	08
5	Lathe-Economatic	M760	05
6	Milling Machine	M710	06

5.2.3.4 Production Calendar

The production calendar is set up to facilitate the usage of the Capacity Requirements Planning sub-system and the Manufacturing Resource Planning system in general. The production calendar is needed not only in a Manufacturing Resource Planning environment but it is also useful for a manual production control and inventory system. People are more aware of time if a production calendar is used. It gives employees a clearer picture of the amount of time to completion date as consecutive numbering of the production calendar is much easier to visualize than the ordinary calendar.

The suggested system is to number the days consecutively only for the days where production is running. This implies the exclusion of weekends, public holidays and any other holidays declared by the company. The weeks are similarly numbered consecutively. The proposed production calendar system is shown in Table 5.5.

Table 5.5

Production Calendar

Ordinary Calendar Day	Day of Week	Production Calendar Week	Production Calendar Day
Jan. 1	Mon.	1	1
" 2	Tue.	1	2
" 3	Wed.	1	3
" 4	Thr.	1	4
" 5	Fri.	1	5
" 6	Sat.		
" 7	Sun.		
" 8	Mon.	2	6
" 9	Tue.	2	7

Each year, the production calendar is revised and a copy issued to each employee for reference. The receipt, scheduling and delivery of orders will be based on the production calendar. The system should be used company-wide as appropriate.

5.3 Testing the Model

The Capacity Requirements Planning Model was tested utilizing a mixture of Argo Engineering and hypothetical components. The dummy components were used as test data because the production flow of these components were relatively more complicated than those of Argo Engineering Limited. This gave the model an opportunity to demonstrate its capability and versatility.

5.3.1 Batch Mode Input Data

The work file and the work center file are stored in permanent files. The data is input by utilizing the editing facility provided by the Disk Operating System (DOS). The contents of these files are illustrated in Tables 5.6 and 5.7.

Table 5.6

Work File Input Data

```
DL3048     02 03
 01 002 01 02
  00 00 00
  02 00 00
 02 003 02 03
  01 00 00
  00 00 00
DL3028     07 08
 01 002 01 02
  00 00 00
  03 00 00
 03 003 02 03
  01 00 00
  02 00 00
 02 001 03 04
  03 00 00
  04 00 00
 04 002 04 05
  02 00 00
  05 00 00
 05 003 05 06
  04 00 00
  06 00 00
 06 004 06 07
  05 00 00
  06 00 00
 06 001 07 08
  06 00 00
  00 00 00
DL3047     07 08
 01 002 01 02
  00 00 00
  02 00 00
 02 001 02 03
  01 00 00
  07 00 00
 07 004 03 04
  02 00 00
  08 00 00
 08 001 04 05
  07 00 00
  05 00 00
 05 003 05 06
  08 00 00
  06 00 00
 06 002 06 07
  05 00 00
  09 00 00
 09 002 07 08
```

Table 5.6 continued

```
  06 00 00
  00 00 00
DL3046     05 06
 01 003 01 02
  00 00 00
  02 00 00
 02 004 02 03
  01 00 00
  07 00 00
 07 001 03 04
  02 00 00
  05 00 00
 05 005 04 05
  07 00 00
  06 00 00
 06 001 05 06
  05 00 00
  06 00 00
DL3044     07 08
 11 001 01 02
  00 00 00
  02 00 00
 02 002 02 03
  11 00 00
  12 00 00
 12 002 03 04
  02 00 00
  05 00 00
 05 003 04 05
  12 00 00
  06 00 00
 06 004 05 06
  05 00 00
  13 00 00
 13 001 06 07
  06 00 00
  09 00 00
 09 001 07 08
  13 00 00
  00 00 00
AAAAAAA123 06 05
 01 003 01 02
  00 00 00
  02 03 00
 02 004 002 03
  01 00 00
  01 00 00
 03 005 02 03
  01 00 00
  01 00 00
 01 001 03 04
```

Table 5.6 Continued

```
  02 03 00
  03 02 00
 03 001 04 05
  01 00 00
  00 00 00
 02 004 04 05
  01 00 00
  00 00 00
BBBBBBB180 04 04
  02 001 01 02
   00 00 00
   01 00 00
  01 005 02 03
   02 00 00
   03 04 00
  03 003 03 04
   01 00 00
   00 00 00
  04 002 03 04
   01 00 00
   00 00 00
 CCCCCCC155 03 04
  01 003 01 02
   00 00 00
   11 00 00
  02 005 02 03
   07 00 00
   10 00 00
  04 004 03 04
   11 00 00
   00 00 00
```

Table 5.7 Work Center File Input Data

```
004
 01 002 A126
 02 005 B345
 03 010 C444
 04 008 B666
```

5.3.2 Interactive Input Data Format

The user invokes the Capacity Requirements Planning Model into "conversational" mode by typing in the file name CRPM.

The displays on the visual display unit are as follows:

```
****************************************
* CAPACITY REQUIREMENTS PLANNING MODEL *
****************************************


Enter today's date (mm/dd/yy):
08/25/82
Enter production calendar day number (3 digits):
200
Enter first day of the week (3 digits):
198
Enter number of components to be processed (3 digits):
008
Enter component part number, start date with reference to
the production calender and production quantity in units on
a single line
(10 alpha-numeric values, 3 digits and 3 digits):
Do it 8 times
DL3048     210 010
DL3028     204 020
DL3047     211 010
DL3046     230 030
```

```
DL3044      222 020
AAAAAAA123 215 010
BBBBBBB180 214 030
CCCCCCC155 235 040
***** PROCESSING .......
```

5.3.3 Output Data Format

The Capacity Requirements Planning Model outputs three reports, namely:

1. Work Center Load Report,
2. Overload Report, and
3. Component Part Scheduling Report.

These reports are depicted in Tables 5.8, 5.9 and 5.10.

The purpose of the Work Center Load Report is to highlight impending capacity problems in the short term before it actually occurs. Management can thus take appropriate action to deal with the situation.

The Overload Report acts as a complement to the Work Center Load Report. It gives a summary of the overload situation. This gives management a better picture of the capacity problem and saves managers the time required to look through each individual Work Center Load Report.

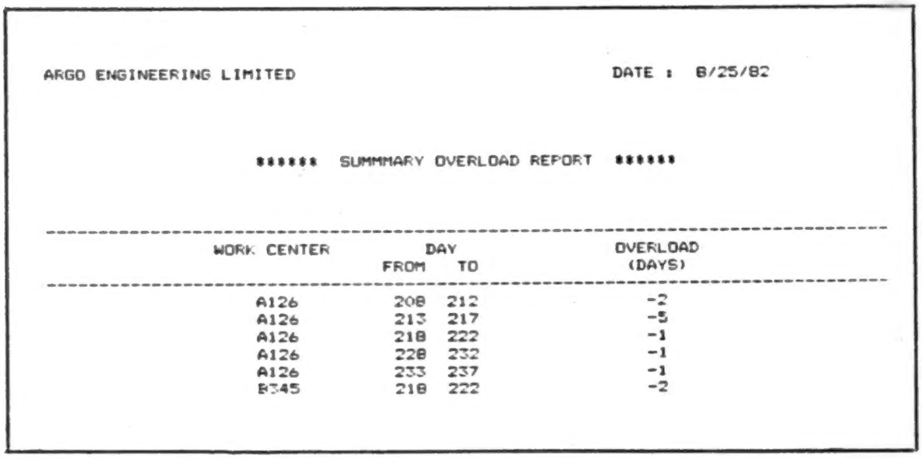
The Component Part Scheduling Report gives a detailed picture by work center of the components utilizing the particular resource. Operators make use of this schedule to determine the priority of processing a batch of components. Operators are made aware beforehand of the time to commence production of a particular batch of components and the completion date.

Table 5.8 Work Center Load Report 1

```
ARGO ENGINEERING LIMITED                                      DATE :  8/25/82


                    ******  WORK CENTER LOAD REPORT  ******


WORK CENTER : A126                                            ACTIVITY :    1

--------------------------------------------------------------------------------
    DAY      CAPACITY NEEDED    CAPACITY AVAILABLE      BALANCE
FROM   TO        (DAYS)                (DAYS)            (DAYS)
--------------------------------------------------------------------------------
 198  202          0                     2                  2
 203  207          2                     2                  0
 208  212          4                     2                 -2
 213  217          7                     2                 -5
 218  222          3                     2                 -1
 223  227          0                     2                  2
 228  232          3                     2                 -1
 233  237          3                     2                 -1
```

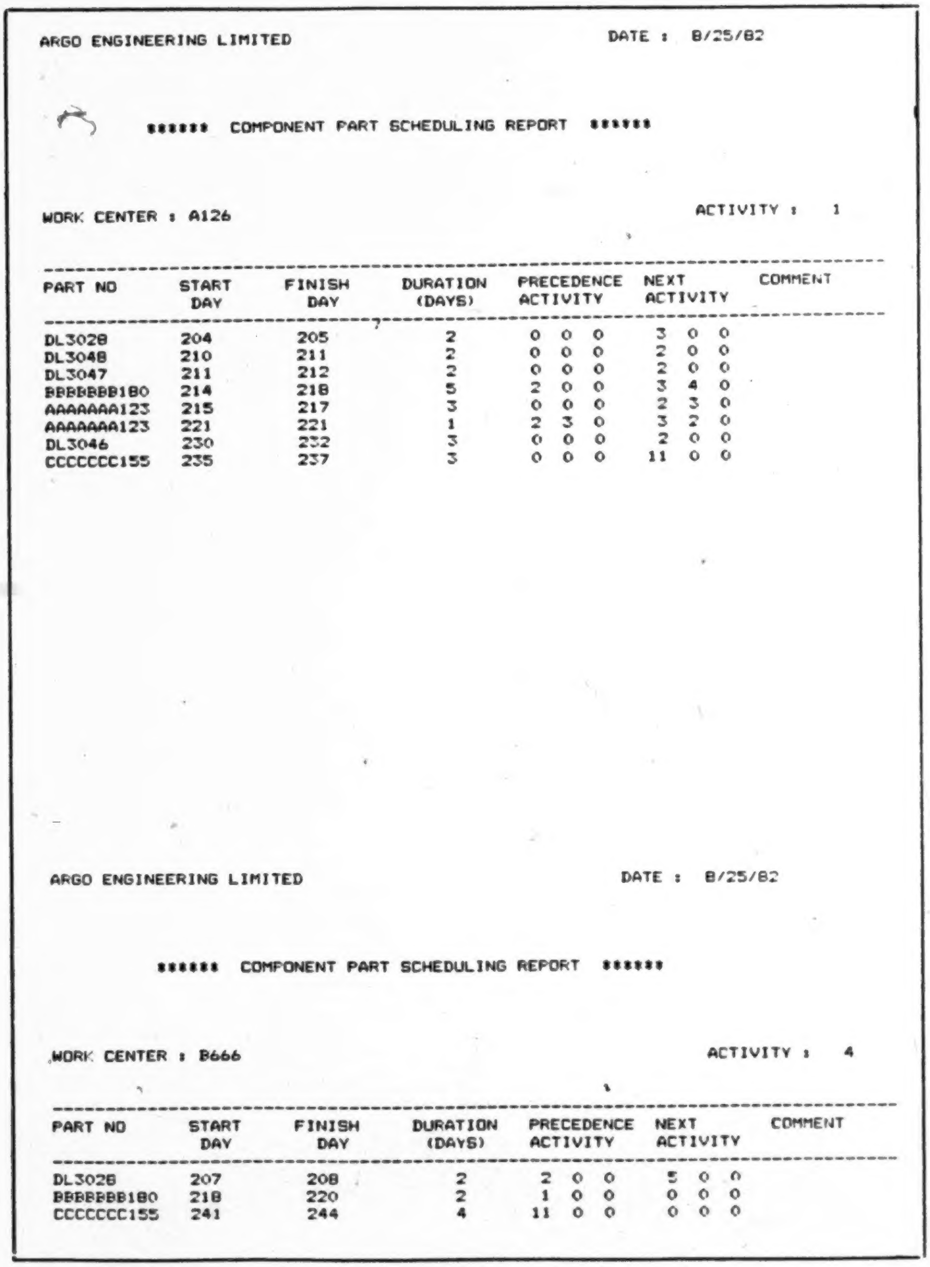
```
ARGO ENGINEERING LIMITED                                      DATE :  8/25/82


                    ******  WORK CENTER LOAD REPORT  ******


WORK CENTER : B666                                            ACTIVITY :    4

--------------------------------------------------------------------------------
    DAY      CAPACITY NEEDED    CAPACITY AVAILABLE      BALANCE
FROM   TO        (DAYS)                (DAYS)            (DAYS)
--------------------------------------------------------------------------------
 198  202          0                     8                  8
 203  207          1                     8                  7
 208  212          2                     8                  6
 213  217          0                     8                  8
 218  222          2                     8                  6
 223  227          0                     8                  8
 228  232          0                     8                  8
 233  237          0                     8                  8
 238  242          2                     8                  6
```

Table 5.9 Summary Overload Report 1



```
ARGO ENGINEERING LIMITED                                   DATE :  8/25/82


                   ******  SUMMARY OVERLOAD REPORT  ******


----------------------------------------------------------------------------
            WORK CENTER            DAY                  OVERLOAD
                           FROM    TO                    (DAYS)
----------------------------------------------------------------------------
                A126        208    212                     -2
                A126        213    217                     -5
                A126        218    222                     -1
                A126        228    232                     -1
                A126        233    237                     -1
                B345        218    222                     -2
```

Table 5.10 Component Part Scheduling Report 1



```
ARGO ENGINEERING LIMITED                              DATE :  8/25/82


          ******  COMPONENT PART SCHEDULING REPORT  ******


WORK CENTER : A126                                         ACTIVITY :    1

-----------------------------------------------------------------------------
PART NO         START     FINISH     DURATION   PRECEDENCE  NEXT        COMMENT
                 DAY        DAY       (DAYS)    ACTIVITY    ACTIVITY
-----------------------------------------------------------------------------
DL3028          204        205          2        0  0  0     3  0  0
DL3048          210        211          2        0  0  0     2  0  0
DL3047          211        212          2        0  0  0     2  0  0
BBBBBBB180      214        218          5        2  0  0     3  4  0
AAAAAAA123      215        217          3        0  0  0     2  3  0
AAAAAAA123      221        221          1        2  3  0     3  2  0
DL3046          230        232          3        0  0  0     2  0  0
CCCCCCC155      235        237          3        0  0  0    11  0  0
```

```
ARGO ENGINEERING LIMITED                              DATE :  8/25/82


          ******  COMPONENT PART SCHEDULING REPORT  ******


WORK CENTER : B666                                         ACTIVITY :    4

-----------------------------------------------------------------------------
PART NO         START     FINISH     DURATION   PRECEDENCE  NEXT        COMMENT
                 DAY        DAY       (DAYS)    ACTIVITY    ACTIVITY
-----------------------------------------------------------------------------
DL3028          207        208          2         2  0  0    5  0  0
BBBBBBB180      218        220          2         1  0  0    0  0  0
CCCCCCC155      241        244          4        11  0  0    0  0  0
```

5.3.4 Discussion of Results

Table 5.8 shows that work center B666 is underloaded for all the days indicated.

Work Center A126 does not have sufficient capacity for five out of eight projected weeks.

The overload situations are summarized clearly in Table 5.9. It defines *"how much"*, *"when"* and *"where"* the overload occurred. There are six overload situations in this particular case.

Table 5.10 indicates the components in the order of priority which work center B666 is required to process. Work center B666 is required to process part number DL3028 first, followed by BBBBBBB180 and finally CCCCCCC155. With respect to each component, the machine operator is informed which is the next activity and what activity precedes the present one. As for example, with reference to work center B666, the part number DL3028 was processed by activity number "2" before passing through this particular work center. When work center B666 which is associated with activity number "4" has completed processing this particular component, it will be passed on to activity number "5". Processing of part number DL3028 has to start on day number two hundred and seven and be completed by day number two hundred and eight. The machine operator is required to insert any relevant comments such as delay in the comment section after the completion of each activity.

5.3.5 Sensitivity Analysis

Similarly, the resolution taken to overcome the short term overload was by increasing the capacity available. The capacity available data in the work center file is edited utilizing the editing facility provided by the Disk Operating System (DOS). The capacity available in department A126 was increased by two days to four days. The capacity availability from the rest of the departments were unaltered. The new set of data is depicted in Table 5.11. The rest of the data was kept intact. The edited data was resimulated according to the procedures described in the previous section.

Table 5.11

Edited Work Center File Input Data

```
004
 01 004 A126
 02 005 B345
 03 010 C444
 04 008 B666
```

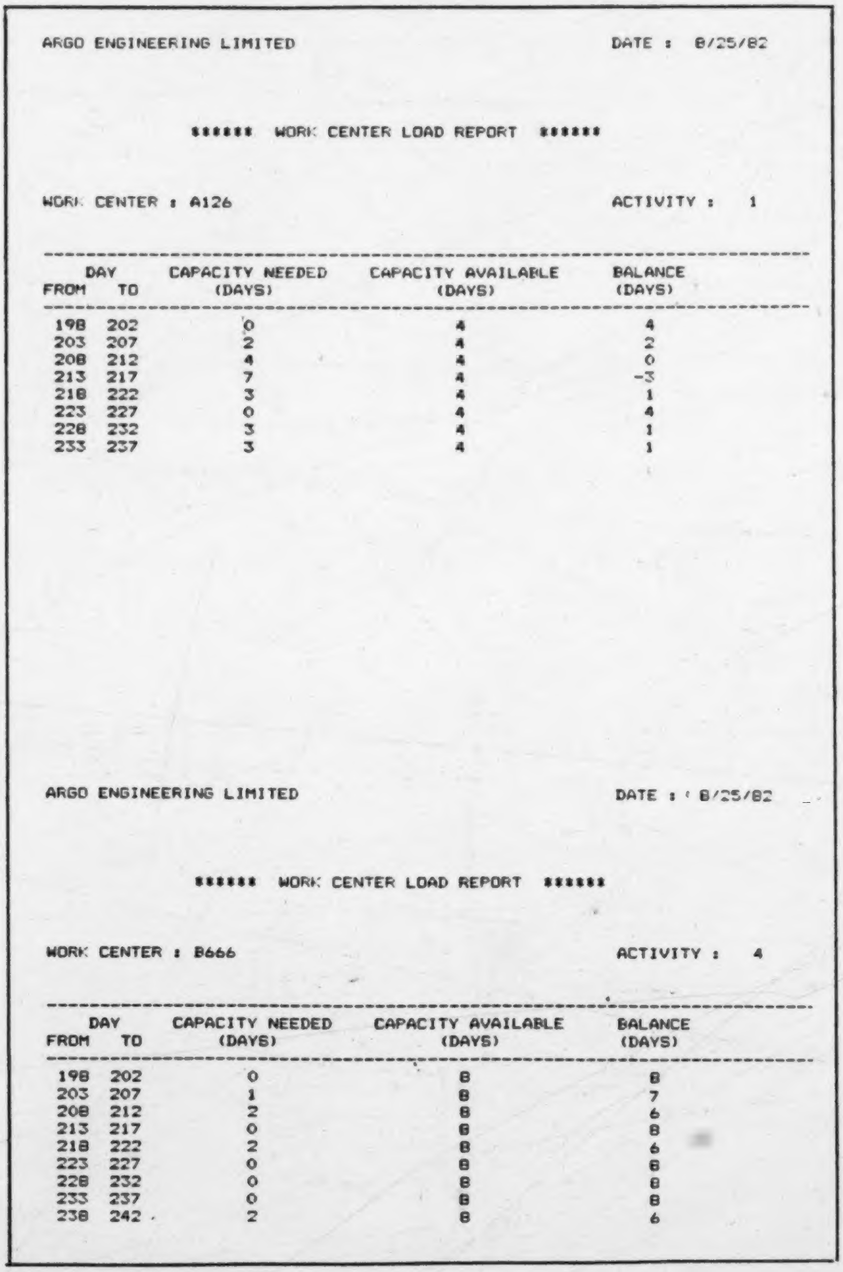
The results are presented in Tables 5.12, 5.13 and 5.14. The Summary Overload Report of Table 5.13 shows that the overload situations have been reduced from six ocassions to two. Work center A126 is overloaded by three days from day number two hundred and thirteen to day number two hundred and seventeen. This is a reduction from an overload of five days. Before increasing the capacity for work center

A126, it was overloaded from day number two hundred and eight to day number two hundred and thirty-seven.

Table 5.14 remains the same as before as there was no alteration to any of the other input parameters, as for example changing the production routing or start date. The increase in capacity does not affect the Component Part Scheduling Report.

This exercise shows that by altering any one of the parameters, the user is able to simulate a plan of action and obtain reasonably accurate results without actually needing to implement the action in practice.

Table 5.12 Work Center Load Report 2

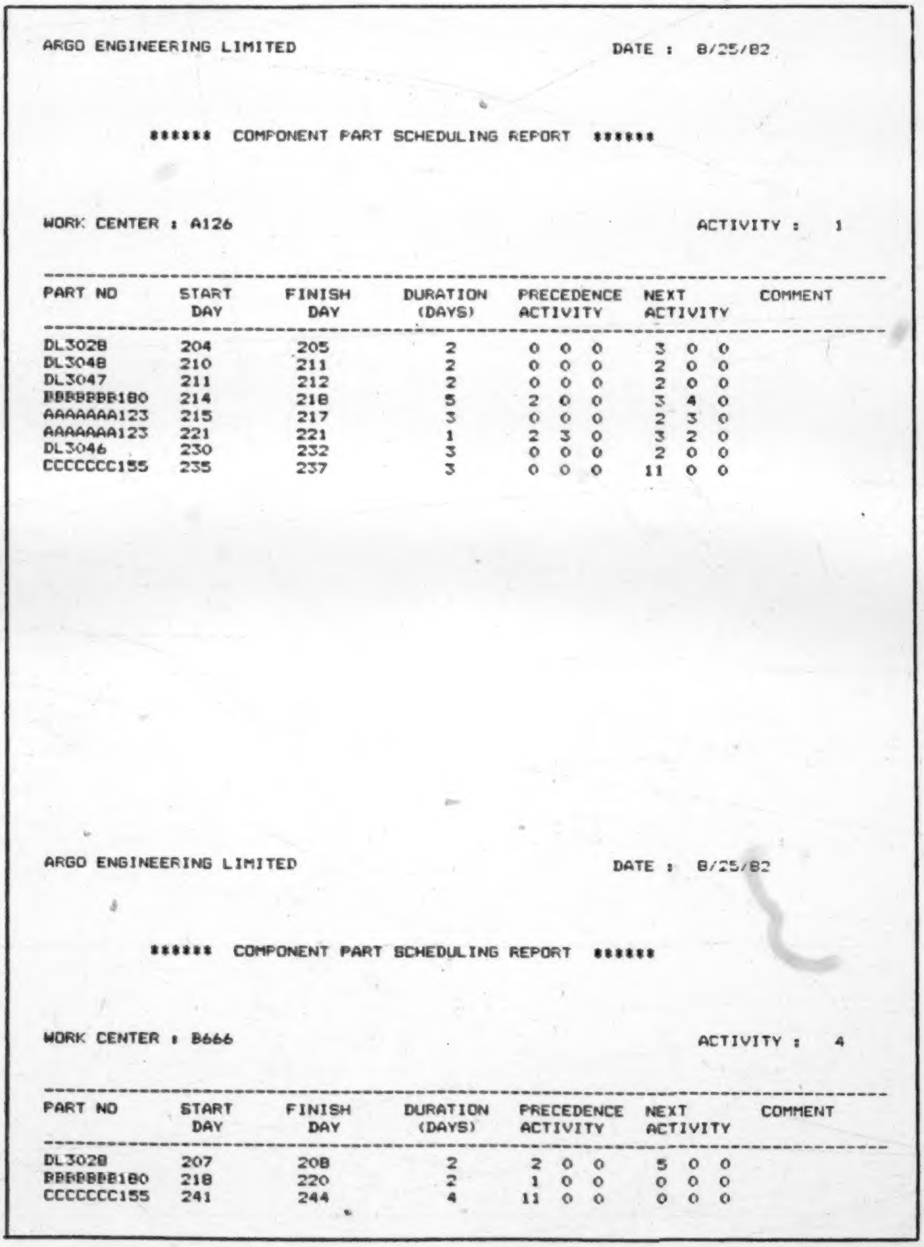


```
ARGO ENGINEERING LIMITED                                      DATE :  8/25/82


              ****** WORK CENTER LOAD REPORT  ******


WORK CENTER : A126                                            ACTIVITY :    1

-----------------------------------------------------------------------------
    DAY      CAPACITY NEEDED    CAPACITY AVAILABLE      BALANCE
FROM   TO        (DAYS)               (DAYS)             (DAYS)
-----------------------------------------------------------------------------
 198  202          0                    4                   4
 203  207          2                    4                   2
 208  212          4                    4                   0
 213  217          7                    4                  -3
 218  222          3                    4                   1
 223  227          0                    4                   4
 228  232          3                    4                   1
 233  237          3                    4                   1









ARGO ENGINEERING LIMITED                                      DATE :  8/25/82


              ****** WORK CENTER LOAD REPORT  ******


WORK CENTER : B666                                            ACTIVITY :    4

-----------------------------------------------------------------------------
    DAY      CAPACITY NEEDED    CAPACITY AVAILABLE      BALANCE
FROM   TO        (DAYS)               (DAYS)             (DAYS)
-----------------------------------------------------------------------------
 198  202          0                    8                   8
 203  207          1                    8                   7
 208  212          2                    8                   6
 213  217          0                    8                   8
 218  222          2                    8                   6
 223  227          0                    8                   8
 228  232          0                    8                   8
 233  237          0                    8                   8
 238  242          2                    8                   6
```

Table 5.13 Summary Overload Report 2

```
ARGO ENGINEERING LIMITED                               DATE :  8/25/82


                ******  SUMMMARY OVERLOAD REPORT  ******


--------------------------------------------------------------------------------
                 WORK CENTER        DAY                  OVERLOAD
                                 FROM   TO                (DAYS)
--------------------------------------------------------------------------------
                     A126         213  217                  -3
                     B345         218  222                  -2
```

Table 5.14 Component Part Scheduling Report 2



```
ARGO ENGINEERING LIMITED                              DATE :  8/25/82


        ******  COMPONENT PART SCHEDULING REPORT  ******


WORK CENTER : A126                                        ACTIVITY :   1

----------------------------------------------------------------------------
PART NO       START     FINISH    DURATION   PRECEDENCE  NEXT        COMMENT
               DAY       DAY       (DAYS)    ACTIVITY    ACTIVITY
----------------------------------------------------------------------------
DL3028        204        205          2        0  0  0     3  0  0
DL3048        210        211          2        0  0  0     2  0  0
DL3047        211        212          2        0  0  0     2  0  0
BBBBBBB180    214        218          5        2  0  0     3  4  0
AAAAAAA123    215        217          3        0  0  0     2  3  0
AAAAAAA123    221        221          1        2  3  0     3  2  0
DL3046        230        232          3        0  0  0     2  0  0
CCCCCCC155    235        237          3        0  0  0    11  0  0
```

```
ARGO ENGINEERING LIMITED                              DATE :  8/25/82


        ******  COMPONENT PART SCHEDULING REPORT  ******


WORK CENTER : B666                                        ACTIVITY :   4

----------------------------------------------------------------------------
PART NO       START     FINISH    DURATION   PRECEDENCE  NEXT        COMMENT
               DAY       DAY       (DAYS)    ACTIVITY    ACTIVITY
----------------------------------------------------------------------------
DL3028        207        208          2        2  0  0     5  0  0
BBBBBBB180    218        220          2        1  0  0     0  0  0
CCCCCCC155    241        244          4       11  0  0     0  0  0
```

6. EVALUATION OF THE MODELS AND SYSTEM

6.1 Advantages of the Models

The Forecasting, Master Production Schedule, Resource Requirements Planning and Capacity Requirements Planning programs developed have a number of common advantages.

1. The programs are interactive whenever they are suitable, for the convenience of the user. This means that the user is able to "communicate" with the programs. The basic advantage of an interactive program is that the user is provided with a step-by-step approach to data entry. The chance of making mistakes is less compared to non-interactive data entry because one is reminded of what to do with respect to data entry.
2. The source program is written in the IBM personal computer Fortran. Fortran is a very common high level language. Most programmers and those trained in the scientific and engineering disciplines are familiar with the language.
3. The models are well documented. For each model, there is a flow diagram to explain the flow of the algorithm, in addition to the description. The variables used in the main program and each sub-routine are defined clearly in Appendix A. If reports are generated as outputs, the terminologies used in these reports are defined to avoid misunderstanding.

4. The models are tailored to the specifications of Argo Engineering Limited.
5. The models are designed for running on an IBM personal computer. There is one main benefit of using the personal computer. The personal computer is a relatively economic system compared to its counterparts; the mini-computer and the mainframe. The present cost of the basic elements of most personal computer systems ranges from $5000 to $15000.
6. The modular build-up of the model permits ease of alteration and refinement to the model. It is possible for the system designer to change any one of the sub-routines or main programs and keep the remaining programs intact.
7. Each model is a separate entity on its own. The company can make use of any one of the models independently. For example, the company might eventually decide that it only wants to implement the Resource Requirements Planning sub-system.

6.2 Evaluation of the IBM Personal Computer System

The basic IBM unit employed to run the models designed in this thesis is illustrated in Table 6.1.

Table 6.1

IBM Basic Unit

1. IBM system unit	
2. 64K RAM memory	
3. Dual disk drive	
4. IBM monochrome display	
5. IBM printer	
6. DOS extended Basic	
7. Operator training manual	
8. Programming seminar	
	$6395
9. Fortran compiler	410
10. 192K RAM memory	1395
Total	$8200

The system unit has a maximum core memory capacity of two hundred and fifty-six kilobytes. It constitutes a one hundred and ninety-two kilobytes and a sixty-four kilobytes random access memory (RAM) boards.

The total cost of the basic IBM unit is $8200.

The utilization of the basic IBM unit to implement a computerized Manufacturing Resource Planning system poses a few practical limitations.

The existing external memory, that is, the diskette limits the size of the programs which were written. A single program must not exceed sixty-five kilobytes in order that it can be compiled. The program had to be split into many sub-programs which were then compiled individually. This is not a limiting factor to the user whose task is just to load the executable file into the core memory and then run the data. However, it is a limitation to the system designer/programmer who wants to expand the program to accommodate more components.

The user is limited to storing a maximum of one hundred and sixty kilobytes on each diskette. On the average, to portray one component using the Critical Path Analysis Technique requires one hundred bytes. Thus, the maximum number of components which can be processed is one thousand and sixty components, assuming that the diskette is a blank. This is sufficient for many small manufacturing companies.

The present Fortran compiler is not perfect in the sense that in certain occassions it is unable to give exact error messages which is certainly needed for efficient debugging of the program. This does not affect the user but is a limitation to the system designer who may need to modify the program as a result of changes in the environment. However, this is likely to improve in the near future as a result of modifications based partly on feedback reponses.

The core memory capacity limitation can be overcome by expanding it to one megabyte. This is achieved by inserting additional random access memory (RAM) boards. The basic unit therefore requires an additional seven hundred and forty-four kilobytes of random access memory (RAM).

The external memory capacity limitations can be overcome by attaching a hard disk drive which has a storage capacity of five megabytes.

The total cost of the expanded system is illustrated in Table 6.2.

Table 6.2

Expanded IBM Unit

1. As above	$ 8200
2. Two 512K RAM memory	1500
3. Hard disk drive	2900
Total	$12600

The IBM Personal Computer-Manufacturing Resource Planning system is suitable for small manufacturing companies provided the data base does not exceed the five megabytes of external storage capacity and one megabyte of core memory capacity. In any case, the hard disk drive is recommended as an "add-on" to make the system more efficient for both the user and system designer. It is possible that the system may also be suitable for medium to large companies provided the data base does not exceed the aforementioned core memory and external storage capacities limit.

6.2.1 Computer Programs Capacity Requirements

The source, object and executable files of the individual models occupy the storage capacity as indicated in Tables 6.3, 6.4, 6.5 and 6.6.

The source file is the file which contains the source codes of the program. The object file is the file which contains the object codes (binary codes) of the program. The object codes are the translated source codes by the IBM Fortran compiler; FOR1 and FOR2. When the object file(s) is/are linked utilizing the SYSTEM LIBRARY, a file called the executable file is created. This is the "run" file. The instructions (codes) of the "run" file will be retrieved, decoded and executed by the central processing unit when the model is invoked by the user.

It is evident from the tables that the largest source file, that is, the Master Production Schedule Report (MPSR) file only occupies 5520 bytes. The main program of the individual models are split into many smaller sub-programs for two reasons:

1. a single program cannot exceed sixty-five kilobytes in order for it to be compiled; and
2. it is intended to create ample storage capacity for expansion of the individual models in the future.

Table 6.3

Forecasting Model Files

File Name	Type of File	Number of Bytes
FM	FOR	2738
AVG	FOR	3446
TREND	FOR	4248
SEASON	FOR	4797
REPORT	FOR	2072
PLOT	FOR	3116
FM	OBJ	4713
AVG	OBJ	9179
TREND	OBJ	13427
SEASON	OBJ	16185
REPORT	OBJ	4024
PLOT	OBJ	8634
FM	EXE	82048

Table 6.4

Master Production Schedule Model Files

File Name	Type of File	Number of Bytes
MPSM	FOR	4344
MPSR	FOR	5520
MPSRL	FOR	1498
MPSINIT	FOR	779
SRPORT	FOR	2159
MPSM	OBJ	7906
MPSR	OBJ	13925
MPSRL	OBJ	2099
MPSINIT	OBJ	1739
SRPORT	OBJ	5244
MPSM	EXE	57856

Table 6.5

Resource Requirements Planning Model Files

File Name	Type of File	Number of Bytes
RRPM	FOR	2840
RRPCAL	FOR	1587
RRPR1	FOR	2218
RRPSR1	FOR	811
RRPPRT	FOR	2067
RRPM	OBJ	5529
RRPCAL	OBJ	4716
RRPR1	OBJ	3694
RRPSR1	OBJ	1650
RRPPRT	OBJ	6990
RRPM	EXE	50944

Table 6.6

Capacity Requirements Planning Model Files

File Name	Type of File	Number of Bytes
CRPM	FOR	2107
GETINP	FOR	1733
CPA	FOR	2200
WCLR	FOR	2423
OVERLR	FOR	1198
CPSR	FOR	2523
CRPINIT	FOR	716
RDWORK	FOR	1113
CRPSTR	FOR	1893
SORT	FOR	1088
CALCAP	FOR	2991
CRPM	OBJ	3395
GETINP	OBJ	4082
CPA	OBJ	4457
WCLR	OBJ	3970
OVERLR	OBJ	1921
CPSR	OBJ	4002
CRPINIT	OBJ	1906
RDWORK	OBJ	1293
CRPSTR	OBJ	3697
SORT	OBJ	2058
CALCAP	OBJ	6752
CRPM	EXE	61184

7. IMPLEMENTATION

7.1 Implementation Guidelines

The best results can be achieved when implementing a Manufacturing Resource Planning system by following the Manufacturing Resource Planning closed-loop philosophy. The basic outline of the implementation steps applicable to Argo Engineering Limited is depicted in Figure 7.1.

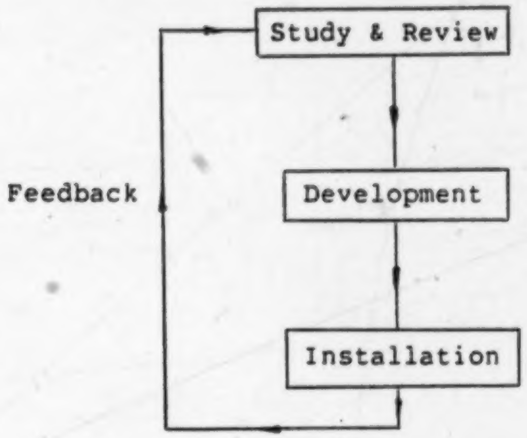


Figure 7.1 Closed-Loop Implementation Plan

7.1.1 Phase 1 - Study and Review

Key people in the company should investigate the workings of Manufacturing Resource Planning, and why the company should be committed to it. These key people should be top managers from engineering, finance, marketing and production planning. Since each of these areas will be directly involved, the managers shold have an understanding of what will be necessary to get Manufacturing Resource Planning working in their company.

There are a number of alternatives open to a company to receive training in Manufacturing Resource Planning. These include:

1. employing consultants to conduct in-house appreciation courses;
2. sending managers for courses offered externally by the consultants;
3. sending managers for courses offered by the Canadian American Production and Inventory Control Society (CAPICS).

After there is a formal commitment to the project, the "key people" group has two important tasks: the first is to establish the project team; the second is to assign accountability. The project team should consist of the top managers in each of the manufacturing and support functions (marketing and finance) which is absolutely necessary to show top management's dedication and support. The team should also contain members of lower level management (first line supervisors) who will provide feedback on day-to-day operations. This is a first step towards achieving a critical mass of talent that is necessary for Manufacturing Resource Planning to work.

The second task of the key group is to assign accountability. It should be established from the start who is going to be responsible for what, and what timetable will be set up for implementation of the system. If individuals are made responsible for specified jobs, there is a tendency that a higher quality job will be done. The general responsibilities of the three functions that will be continously involved may be specified as follows:

Marketing

1. responsible for forecasts of consumer demand, which "drive" the Master Production Schedule; and
2. distribution and model mix should also be the responsibility of marketing.

Finance

1. responsible for financing and control of finished goods inventory in terms of total investment, credit and receivables; and
2. responsible for the financing of the Manufacturing Resource Planning project.

Production Planning and Control

1. responsible for development and performance of the Master Production Schedule within the contraints developed by marketing;
2. controls engineering changes - Bill of Materials; and
3. establishes and maintains inventory accuracy.

Detailed education and training is the next major task that the project team should address. The objective of this part of the project is to give the people who will be operating the system an understanding of the system, and the means to use it effectively. Education and training must translate the general principles of Manufacturing Resource Planning into the specifics of operations within the company. The project team can design a program to train their own staff; beginning with those who are going to be affected the earliest.

The education and training process will exact a great amount of time and effort from management, especially in the first 18-24 months.

Even after the system is up and running, "maintenance training" in the form of refresher courses will be necessary. This will keep people from developing bad habits and helps to stimulate fresh thinking and analysis. Refresher courses will help to maintain that "critical mass" of trained, experienced personnel to keep Manufacturing Resource Planning operating effectively.

7.1.2 Phase 2 - Development

After completion of phase 1, there should be a commitment of people and top management to accomplish a successful Manufacturing Resource Planning implementation. Everyone should have a clear idea of what is required to be done to achieve the desired results.

The first step is to ensure that the inventory record is 95% accurate [24]. The procedure for achieving this is covered in E.S. Kombe's thesis. The second step is to implement the procedures for setting up an identification system (Bill of Materials) as detailed in E.S. Kombe's thesis.

7.1.2.1 Time Study Procedure

The next step is to establish time study records for the production of each component.

There are two categories of work measurement procedure; direct and indirect.

The direct work measurement procedure includes:

1. time study, and
2. activity sampling.

The indirect work measurement procedure includes:

1. synthetic timing,
2. predetermined motion time systems, and
3. analytical estimating.

Time study accounts for the majority of the exercises conducted. Therefore, the time study procedure will be elaborated.

1. The engineer studies the component drawing to be time studied.
2. The total job is broken down into smaller bits called elements. Each element is chosen to have a definite beginning and end (break point which is visible or audible).
3. Each element is timed by a stop watch many times until reasonable consistency is achieved. At the same time each element is rated on a suitable scale of pace and

recorded.

4. At the end of the study, each element is multiplied by the rating factor. This is called the elemental normal time. The equation for deriving the elemental normal time is:

   Normal time = Observed time * Rating factor %

5. The elemental standard time is derived by taking into account contingency allowances. The equation for deriving the elemental standard time is:

   Standard time = Normal time * 1/(1 - Allowance %)

6. The elemental shop planning time is derived by taking into account the efficiency of the shop or department or machine as appropriate. The equation for deriving the elemental shop planning time is:

   Shop planning time = Standard time / Efficiency %

7. The sum of these elemental shop planning times is the total time to produce the component.

The time study may be recorded in the observation sheet as depicted in Table 7.1.

Table 7.1 Time Study Observation Form

Argo Engineering Limited

Time Study Observation Form

Part Number:

Date:

Part Description:

Study Commenced:

Study End:

No.	Elem't	Freq'cy	Obser'd Time (sec)	Rat'g	Relaxat'n Allow'ces	Normal Time (sec)	Std. Time (sec)	Shop Plan Time (sec)

Total

7.1.3 Phase 3 - Installation

The system should by now be ready for a trial run. There are three methods of implementation. The team may select: pilot program, total system implementation or parallel system implementation.

The complete switch-over approach drops all past procedures and implements the new complete method company-wide.

The parallel approach is when both systems are being used at the same time.

The third method is the pilot approach which takes a sample, which may be one or two, of the product lines to be tested on a trial basis. This is a safer method as the users are given the opportunity to get used to the system before it is implemented company-wide. It is possible to study the possible causes of failure, learn from it and rerun the system again after resolving the problems.

The pilot approach is highly recommended for installation in Argo Engineering Limited, if and when the company decides to implement a Manufacturing Resource Planning system in the near future.

The pilot program is a trial run of the system on one or a group of product lines. The Manufacturing Resource Planning system is implemented on a stage by stage basis. Initially, a group of product lines, as for example dock levellers is selected for testing the system. The first step is to test the Material Requirements Planning sub-system.

The Bill of Materials of the chosen product line, assumed to be dock levellers in this case, are loaded into the system. The Master Production Schedule is set up following the procedures outlined in the Master Production Schedule chapter. The Material Requirements Planning sub-system takes the Master Production Schedule for end items and explodes the end item Bill of Materials into its lower level requirements. Details of how to utilize the Material Requirements Planning sub-system is given in D. Quek's engineering report.

After the Material Requirements Planning sub-system has been implemented and has settled down, the project team can begin training and implementation of the Capacity Requirements Planning sub-system. The procedures for utilizing the Capacity Requirements Planning sub-system is discussed in this thesis.

Once the system is verified and the desired results are achieved, the pilot run can be systematically expanded until all product lines are on line. After implementation has successfully been completed, the project team should again review its progress with top management. It should be top management's responsibility to provide continued encouragement and support to ensure that people do not slip back into the old system.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Benefits of Manufacturing Resource Planning

Once the entire system is running successfully, Argo Engineering Limited can expect to gain the benefits which are summarized by Fuchs [36] as follows:

Master Planning and Scheduling

1. orders tracked and repromised in a timely manner;
2. forecast maintained current;
3. continuous monitoring of performance to schedule;
4. planned and controlled production;
5. fewer emergencies (less expediting).

Inventory and Material Planning

1. proper participation in what-to-stock decisions;
2. inventory record accuracy;
3. a master plan for complete material management;
4. tool inventory control.

Capacity Planning and Control

1. resource planning;
2. shop load forecast;
3. priorities maintained by material availability;
4. fewer setups;
5. reduced and correct lead times.

Manufacturing Resource Planning does not discriminate size, nature and location of a company. It is very difficult to draw the line as to what size of company should consider implementing a Manufacturing Resource Planning system. It is suggested that if a company shows symptoms of high inventory costs, low productivity and frequent missed delivery promises, the company should consider installing a Manufacturing Resource Planning system [21].

However, the author believes that a company should consider implementing a Manufacturing Resource Planning system when it is still "small". It is normally easier to manage and control the transformation to Manufacturing Resource Planning in a small company.

8.2 Strengths and Weaknesses of the System

The strengths of the various simulation models have been discussed in chapter 6. A recapitulation of the advantages discussed are listed as follows:

1. interactive mode of operation;
2. written in Fortran;
3. proper documentation;
4. tailored to the specifications of Argo Engineering Limited;
5. designed for running on an IBM personal computer;
6. modular design permits ease of alteration and refinement;
7. independent application of the models is permissible.

The weaknesses of the individual models are outlined below:

1. The Forecasting Model does not incorporate economical, sociological and psychological factors in computing the forecast. The individual must be made aware of this limitation. Adjustments may be necessary to account for these factors.
2. The Master Production Schedule Model at present utilizes the Economic Order Quantity formula in computing the Master Production Schedule job lot size. The above formula may or may not provide the "best" results for Argo Engineering Limited. Over time, based on experience the company may employ other lot sizing techniques as deemed appropriate.
3. The Master Production Schedule and Capacity Planning Models do not have the capability of producing material and labour costs reports respectively.

8.3 Recommendations for Future Study

The major sub-systems discussed in this thesis can be expanded to include the following extensions in order to make the system more sophisticated and versatile.

1. The Forecasting Model can be extended to incorporate economical, sociological and psychological factors in its computation. This will probably help to reduce the forecast error.

2. The Master Production Schedule Model can be extended to provide material cost output data in the long and short term. This will be useful for financial planning and control. In addition, the next logical extension is to include a sub-routine for processing and displaying statistical quality control information.
3. The extension in the Capacity Planning Models concerns the inclusion of the facility for providing labour cost output data. Again, this will serve as useful information for financial planning and control.

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APPENDIX A

GLOSSARY OF VARIABLES USED IN THE COMPUTER PROGRAMS

FORECASTING MODEL

ADEMD - Actual historical sales data
AERR - Average error based on specified range of smoothing constants
ALFA - Best smoothing constant
ALPHA - Smoothing constants
BSDMD - Actual historical sales data used as the base series for the SEASON sub-routine
CAERR - Total average error based on best smoothing constant
CFCAST - Current smoothed demand data
CMAD1 - Total mean absolute deviation from AVG sub-routine
CMAD2 - Total mean absolute deviation from TREND sub-routine
CMAD3 - Total mean absolute deviation from SEASON sub-routine
CMSE - Total mean standard error based on best smoothing constant
EWMA - Exponential Weighted Moving Average
FCAST - Forecast output data which can be derived from either FCAST1 or FCAST2 or FCAST3
FCAST1 - Forecast output data derived from AVG sub-routine
FCAST2 - Forecast output data derived from TREND sub-routine
FCAST3 - Forecast output data derived from SEASON sub-routine
LFCAST - Smoothed demand data of previous period
MAD - Mean absolute deviation based on specified range of smoothing constant
MSE - Mean standard error based on specified range of smoothing constants
TAERR - Total average error based on specified range of smoothing constants
TMAD - Total mean absolute deviation based on specified range of smoothing constants
TMSE - Total mean standard error based on specified range of smoothing contants

MASTER PRODUCTION SCHEDULE MODEL

ARRWK - An array of week numbers (MPSRL routine)
AWEEK - An array of week numbers
BKINGS - Bookings
BKLOG - Backlog
CLASS - Classification A/B/C
DESCRP - Description
EOQ - Economic Order Quantity
GROSSF - Gross Forecast
GROSSR - Gross Requirements
HORZON - Horizon
IWEEK - Number of weeks (MPSR routine)
IWK - Number of weeks (MPSRL routine)
ISHRNK - Shrinkage (MPSRL routine)
JLSIZE - Job lot size
LTCODE - Lead time code
MAXQTY - Maximum quantity
MINQTY - Minimum quantity
MLT - Manufacturing lead time
MORB - Make or Buy
MPS - Master Production Schedule
MPSCH - Master Production Schedule (MPSRL routine)
MPSR - Subroutine name: Master Production Schedule Report
MPSRL - Subroutine name: Master Production Schedule Receipt List Report
NETF - Net forecast
NETREQ - Net requirement
NWEEK - Number of weeks desired by the user to be processed and compiled for the Master Production Schedule Report
ORDQTY - Order quantity
PARTNO - Part number
PLT - Purchase lead time
ROL - Reorder level
SOHAND - Stock on hand
SRPORT - Subroutine name: it computes the output data for the Master Production Schedule Report

RESOURCE REQUIREMENTS PLANNING MODEL

CPAVAL - Capacity available array
CPNEED - Capacity needed array
DEPTCD - Department code array
HRAVAL - Machine hours available
ITYPE - Type of output
IYEAR - Beginning year
JDEPT - Department code array for the Overload Report
JYEAR - Year array for the Overload Report
JYHALF - 1st half or 2nd half of the year
JVALUE - Negative value of HRAVAL
MCAP - Machine capacity array
NDEPT - Number of departments array
NEG - Subscript used to identify the negative value in HRAVAL array
NOPROD - Number of products
NYRS - Number of years
PRODCD - Product code array
PRODQT - Production quantity
RRPCAL - Subroutine name: it calculates the output data for the Long Term Work Center Report
RRPPRT - Subroutine name: it prints the output data for the Long Term Work Center Report
RRPR1 - Subroutine name: it prints the Long Term Work Center Report headings
RRPSR1 - Subroutine name: it prints the Overload Report
STDHR - Standard hour array
TOTCAP - Total capacity array

CAPACITY REQUIREMENTS PLANNING MODEL

ACTCD - Activity code
CALCAP - Subroutine name: it calculates the capacity needed
CPA - Subroutine name: Critical Path Analysis
CPAMT - Production amount for the component
CPID - Component identification
CPSR - Subroutine name: Component Part Scheduling Report
CRIPTS - "Critical Points". It indicates the start/finish date of that particular activity
CRPINIT - Subroutine name: it initializes the variables in the common block area /STRF/
CRPSTR - Subroutine name: it stores information in common block /STRF/
DESTND - Destination node (TO)
DURATN - Duration for that activity code
GETINP - Subroutine name: it reads from the data files; WORKFL and CENTREFL and stores the information in common block /WORK/ and /CENTR/ respectively
ICP - Component identification
IDEST - Destination node
IDUR - Duration of the activity
IFIN - Finish date
INEXT - Next activity
IPRE - Precedence activity
IPTR - Pointer to the next vacant space in array ICP, ISTART,IFIN,IDUR,ISORCE,IDEST,IPRE,INEXT
ISTART - Start date
ISORCE - Source node
IWORK - Information in IWORK is a duplicate of ISTART. Array IWORK is used for the purpose of sorting out the start dates in ascending order
MACT - Maximum number of machines in the file 'CENTREFL'
MACTCD - Machine activity code
MAXACT - Maximum number of activities for that component
MAXCAP - Maximum capacity
MAXND - Maximum nodes for that component
MCODE - Machine code (Work center number)
NACT - Activity number
NCOMP - Component number
NUMCP - Number of components
NDUR - Duration of activity
NEXT - Next activity
NFIN - Finish date
OVERLR - Subroutine name: Overload Report
RDWORK - Subroutine name: it reads information from the common block /WORK/
SORT - Subroutine name: it sorts the start dates in ascending order
WCLR - Subroutine name: Work Center Load Report

APPENDIX B - The Computer Programs

```
$TITLE:'MSc. THESIS PROGRAM - 1'
$SUBTITLE:'FORECASTING MODEL'
      PROGRAM FM
C
C  *****************************************************
C  *  THIS IS THE MAIN PROGRAM.                        *
C  *  THIS PROGRAM SELECTS THE BEST EXPONENTIAL        *
C  *  WEIGHTED MOVING AVERAGE (EWMA) MODEL BY          *
C  *  COMPARING THE RESULTS OF EACH INDIVIDUAL MODEL   *
C  *  BASED ON THE CRITERION OF TMAD.                  *
C  *****************************************************
C
C
      COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     *               FCAST1(25), FCAST2(25), FCAST3(25)
C
      REAL ADEMD, FCAST, BSDMD, FCAST1, FCAST2, FCAST3
C
      REAL CMAD1, CMAD2, CMAD3
C
      CHARACTER*8 DATE
      CHARACTER*40 FITEM,PERIOD
C
C READ INPUT VARIABLES
C
      WRITE(*,888)
 888  FORMAT(' ',23('*'),/,
     &' ','* FORECASTING MODEL  *',/,
     &' ',23('*'),/,' ')
C
      WRITE(*,1)
 1    FORMAT(' ','ENTER TODAY"S DATE (MM/DD/YY):')
      READ(*,2) DATE
 2    FORMAT(BN,A8)
      WRITE(*,3)
 3    FORMAT(' ','ENTER FORECAST ITEM ',
     &'(40 ALPHA-CHARACTERS:')
      READ(*,4) FITEM
 4    FORMAT(BN,A40)
C
      WRITE(*,55)
 55   FORMAT(' ','ENTER FORECAST FOR MONTH/',
     &'1 YEAR [HALF]',/,
     &' ','PRESS 1 FOR MONTH',/,
     &' ','PRESS 2 FOR 1 YEAR [HALF]')
      READ(*,12) MORY
 12   FORMAT(BN,I1)
C
      IF (MORY .EQ. 1) THEN
         WRITE(*,13)
 13     FORMAT(' ','ENTER FORECAST PERIOD',/,
     &  ' ','(EXAMPLE: JAN 1982 TO DEC 1982)',/,
     &  ' ','(40 ALPHA-CHARACTERS):')
        READ(*,14) PERIOD
 14     FORMAT(BN,A40)
      ELSE
        WRITE(*,15)
 15     FORMAT(' ','ENTER FORECAST PERIOD',/,
     &  ' ','(EXAMPLE:1982 TO 1987)',/,
     &  ' ','(40 ALPHA-CHARACTERS):')
        READ(*,16) PERIOD
 16     FORMAT(BN,A40)
      ENDIF
C
C ENTER DATA FOR BSDMD & ADEMD
C
      WRITE(*,17)
 17   FORMAT(' ','ENTER 14 DATA FOR BASE SERIES',
     &' DEMAND',/,' ','ON A SINGLE LINE.',
     &' (XXXXX.X REALS EACH):')
      READ(*,18) (BSDMD(I),I=1,14)
 18   FORMAT(BN,F7.1,13F8.1)
C
      WRITE(*,19)
 19   FORMAT(' ','ENTER 12 DATA FOR PAST HISTORICAL',
     &' DEMAND',/,' ','ON A SINGLE LINE.',
     &' (XXXXX.X REALS EACH):')
      REAL(*,20) (ADEMD(I),I=1,12)
 20   FORMAT(BN,F7.1,11F8.1)
C
      WRITE(*,21)
 21   FORMAT(' ','**** PROCESSING ......')
C
C OPEN OUTPUT FILE
C
      OPEN (6,FILE='PRN')
C
C
C INITIALISATION
C
      SMALL = 9999.9
C
      CALL AVG(CMAD1)
      CALL TREND(CMAD2)
      CALL SEASON(CMAD3)
C
      SMALL = CMAD1
      IPRT = 1
      IF ( CMAD2 .LT. SMALL) GOTO 10
      GOTO 11
 10      SMALL = CMAD2
         IPRT = 2
 11      IF ( CMAD3 .LT. SMALL) GOTO 15
         GOTO 25
 15           SMALL = CMAD3
              IPRT = 3
 25    GOTO (100,120,130), IPRT
 100   CALL REPORT(1)
       GOTO 140
 120   CALL REPORT(2)
       GOTO 140
 130   CALL REPORT(3)
 140   CALL PLOT
C
C
      STOP
      END
C
C
C
C
      SUBROUTINE AVG (CMAD1)
C
C     *****************************************************
C     *   THIS SUBROUTINE CALCULATES THE FORECAST         *
C     *   BASED ON THE BEST ALPHA, DERIVED BY AVERAGING   *
C     *   THE RESULTS OF TWO DIFFERENT CRITERIA.          *
C     *   THIS SUBROUTINE WOULD BE SELECTED IF THE        *
C     *   COMPONENTS OF DEMAND EXHIBIT 'RANDOMNESS'.      *
C     *****************************************************
C
C
C     INPUT PARAMETER  : NONE
C     OUTPUT PARAMETER : CMAD1
C
C
C
      DIMENSION LFCAST(13), CFCAST(12),
     &          AERR(12), TAERR(30), MAD(12), TMAD(30),
     &          MSE(12), TMSE(30), ALPHA(30)
C
      COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     &               FCAST1(25), FCAST2(25), FCAST3(25)
C
C
      REAL CFCAST, LFCAST, ADEMD, AERR, TAERR, MAD, TMAD,
     &     MSE, TMSE, SMALL, ALPHA, LNUM, AALPHA, ALFA,
     &     CAERR, CMAD1, CMSE, PFCAST, LADEMD, FCAST,
     &     FCAST1
C
C
C INITIALIZATION
C
      DO 5 I=1,25
         CFCAST(I)=0.0
         LFCAST(I)=0.0
         FCAST(I)=0.0
 5    CONTINUE
C
      DO 10 J=1,12
```

```
         AERR(J)=0.0
         MAD(J)=0.0
         MSE(J)=0.0
 10   CONTINUE
C
      DO 15 K=1,30
         TAERR(K)=0.0
         TMAD(K)=0.0
         TMSE(K)=0.0
         ALPHA(K)=0.0
 15   CONTINUE
      SMALL=9999.9
      LNUM=0.0
      AALPHA=0.0
C
C     THIS LOOP COMPUTES THE BEST VALUE OF ALPHA BY
C     COMPARING THE TOTAL MEAN ABSOLUTE DEVIATION (TMAD)
C     AND THE TOTAL MEAN SQUARED DEVIATION (TMSE)
C     ASSOCIATED WITH EACH ALPHA VALUE. THE BEST ALPHA
C     CORRESPONDS TO THE LOWEST TMAD AND TMSE. THE 2
C     ALPHAS ARE AVERAGED TO YIELD THE BEST ALPHA.
C
C
      DO 100 L=1,30
         LNUM=L
         ALPHA(L)=LNUM/100
C
C     THIS LOOP COMPUTES THE TMAD AND TMSE.
C
         J=1
         LFCAST(1)=ADEMD(1)
         DO 50 I=1,12
            CFCAST(I)=ALPHA(L)*ADEMD(I)+(1-ALPHA(L))
     &                *LFCAST(J)
            J=I+1
            LFCAST(J)=CFCAST(I)
            AERR(I)=ADEMD(I)-CFCAST(I)
            TAERR(L)=TAERR(L)+AERR(I)
            MAD(I)=ABS(AERR)
            TMAD(L)=TMAD(L)+MAD(I)
            MSE(I)=ABS(AERR(I))**2
            TMSE(L)=TMSE(L)+MSE(I)
 50     CONTINUE
            IF (TMAD(L).LT.SMALL) SMALL=TMAD(L)
            ALPHA1=ALPHA(L)
            IF (TMSE(L).LT.SMALL) SMALL=TMSE(L)
            ALPHA2=ALPHA(L)
 100  CONTINUE
            AALPHA=(ALPHA1+ALPHA2)/2
C
C     THIS LOOP COMPUTES THE SMOOTHED DEMAND (FORECASTS)
C     USING THE BEST ALPHA.
C
C
```

```
          ALFA=AALPHA
          J=1
          LFCAST(1)=ADEMD(1)
C
       DO 150 I=1,12
          FCAST1(I)=ALFA*ADEMD(I)+(1-ALFA)*LFCAST(J)
          J=I+1
          LFCAST(J)=FCAST1(I)
          AERR(I)=ADEMD(I)-CFCAST(I)
          CAERR=CAERR+AERR(I)
          MAD(I)=ABS(AERR(I))
          CMAD1=CMAD1+MAD(I)
          MSE(I)=ABS(AERR(I))**2
          CMSE=CMSE+MSE(I)
 150   CONTINUE
C
C     THIS LOOP EXTRAPOLATES THE SMOOTHED FORECASTS.
C
       J = 1
       K = 12
       DO 200 I = 13,25
          FCAST1(I) = ALFA*ADEMD(J)+(1-ALFA)*LFCAST(K)
          J = J+1
          K = K-1
          LFCAST(K) = FAST1(I)
200    CONTINUE
C
       RETURN
       END
C
C
C
C
       SUBROUTINE TREND (CMAD2)
C
C     ***************************************************
C     * THIS ROUTINE CALCULATES THE FORECAST BASED ON   *
C     * THE BEST COMPUTED ALPHA, DERIVED BY AVERAGING   *
C     * THE RESULTS OF TWO DIFFERENT CRITERIA. THIS     *
C     * ROUTINE WOULD BE SELECTED IF THE COMPONENTS     *
C     * OF DEMAND EXHIBIT 'TREND'.                      *
C     ***************************************************
C
C     INPUT PARAMETER  : NONE
C     OUTPUT PARAMETER : CMAD2
C
C
C
      DIMENSION CFCAST(13), TAERR(30),
     &          TMAD(30), TMSE(30), ALPHA(30), CATRD(12),
     &          CATA(12), LFCAST(13), MAD(12), MSE(12),
     &          AERR(12)
C
      COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     &                FCAST1(25), FCAST2(25), FCAST3(25)
C
      REAL CFCAST, LFCAST, ADEMD, TAERR, TMAD,
     &     TMSE, SMALL, ALPHA, AALPHA, FCAST, FCAST2,
     &     CATRD, CATA, CAERR, CMAD2, CMSE, ALFA, MAD, MSE
C
C
C     INITIALISATION
C
C
      DO 1 I = 1,25
         CFCAST(I) = 0.0
         LFCAST(I) = 0.0
 1    CONTINUE
C
      DO 2 J=1,12
          CATRD(J)=0.0
          CATA(J)=0.0
          MSE(J)=0.0
          AERR(J)=0.0
 2    CONTINUE
C
      SMALL = 9999.9
      DO 10 L = 1,30
         TAERR(L) = 0.0
         TMAD(L) = 0.0
         TMSE(L) = 0.0
         ALPHA(L) =0.0
 10   CONTINUE
C
C THIS LOOP COMPUTES THE BEST VALUE OF ALPHA BY COMPARING
C THE TMSE AND TMAD ASSOCIATED WITH EACH INDIVIDUAL ALPHA.
C THE BEST ALPHA CORRESPONDS TO THE LOWEST TMSE AND TMAD.
C THE TWO ALPHAS ARE AVERAGED TO YIELD THE BEST ALPHA.
C
C
      DO 300 L = 1,30
         LNUM = L
         ALPHA(L) = LNUM/100.0
C
C THIS LOOP COMPUTES THE TMSE AND TMAD.
C
         J=1
         LFCAST(1)=ADEMD(1)
         DO 50 I = 1,12
            CFCAST(I) = ALPHA(L) * ADEMD(I) +
     &                  (1 - ALPHA(L)) * LFCAST(J)
            J = I + 1
            LFCAST(J) = CFCAST(I)
 50      CONTINUE
C
         DO 100 I = 1,12
            CATRD(I) = CFCAST(I) - LFCAST(I)
100      CONTINUE
```

```
         PATA = 0.0
C
         DO 150 I = 1,12
            CATA(I) = ALPHA(L) * CATRD(I) +
      &                ((1 -ALPHA(L)) * PATA)
            PATA = CATA(I)
 150     CONTINUE
C
         DO 200 I = 1,12
            K = I + 1
            FCAST(K) = CFCAST(I) + (1/ALPHA(L)) * CATA(I)
 200     CONTINUE
C
         DO 250 K = 2,12
            AERR(K) = ADEMD(K) - FCAST(K)
            TAERR(L) = TAERR(L) + AERR(K)
            MAD(K) = ABS(AERR(K))
            TMAD(L) = TMAD(L) + MAD(K)
            MSE(K) = ABS(AERR(K)) ** 2
            TMSE(L) = TMSE(L) + MSE(K)
            IF (TMAD(L) .LT. SMALL) SMALL = TMAD(L)
            ALPHA1 = ALPHA(L)
            IF (TMSE(L) .LT. SMALL) SMALL = TMSE(L)
            ALPHA2 = ALPHA(L)

 250     CONTINUE
            AALPHA = (ALPHA1 + ALPHA2) / 2
 300  CONTINUE
            ALFA = AALPHA
C
C THIS LOOP COMPUTES THE SMOOTHED DEMAND (FORECASTS)
C USING THE BEST ALPHA.
C
      J=1
      LFCAST(1)=ADEMD(1)
      DO 350 I = 1,12
         CFCAST(I) = ALFA * ADEMD(I) + (1 - ALFA) *
     &               LFCAST(J)
         J = I + 1
         LFCAST(J) = CFCAST(I)
 350  CONTINUE
C
      DO 400 I =1,12
         J = I
         CATRD(I) = CFCAST(I) - LFCAST(J)
 400  CONTINUE
      PATA = 0.0
C
      DO 450 I = 1,12
         CATA(I) = ALFA * CATRD(I) + (1 - ALFA) * PATA
         PATA = CATA(I)
 450  CONTINUE
C
      DO 500 I = 1,12
```

```
         K = I + 1
         FCAST2(K) = CFCAST(I) + (1/ALFA) * CATA(I)
 500  CONTINUE
C
C     THIS LOOP EXTRAPOLATES THE SMOOTHED FORECASTS.
C
      N = 2
      DO 550 K = 14,25
         I = 13
         FCAST2(K) = CFCAST(I) + (1/ALFA + N-1) * CATA(I)
         N = N+1
 550  CONTINUE
C
      DO 600 K = 2,12
         I = K
         AERR(I) = ADEMD(I) - FCAST(K)
         CAERR = CAERR + AERR(I)
         MAD(I) = ABS(AERR(I))
         CMAD2 = CMAD2 + MAD(I)
         MSE(I) = ABS(AERR(I) ** 2)
         CMSE = CMSE + MSE(I)
 600  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE SEASON (CMAD3)
C
C     *****************************************************
C     *  THIS SUBROUTINE CALCULATES THE FORECAST BASED    *
C     *  ON THE BEST COMPUTED ALPHA, DERIVED BY           *
C     *  AVERAGING THE RESULTS OF TWO DIFFERENT CRITERIA.*
C     *  THIS SUBROUTINE WOULD BE SELECTED IF THE         *
C     *  COMPONENTS OF DEMAND EXHIBIT 'SEASON'.           *
C     *****************************************************
C
C
C
C     INPUT PARAMETER  :  NONE
C     OUTPUT PARAMETER :  CMAD3
C
C
      DIMENSION BS(12), DRATIO(12),
     &          SAR(12), ASAR(12), TREN(12), ERATIO(12),
     &          CFCAST(12), AERR(12), TAERR(30), MAD(12),
     &          TMAD(30), MSE(12), TMSE(30), ALPHA(30)
C
      COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     &               FCAST1(25), FCAST2(25), FCAST3(25)
C
C
```

```
C
      REAL BS, DRATIO, ADEMD, BSDMD, SAR, ASAR, TREN,
     &     ERATIO, CFCAST, AERR, TAERR, MAD, TMAD, MSE,
     &     TMSE, ALPHA, ISAR, ITREND, AALPHA, ALFA,
     &     FCAST, CAERR, CMAD3, CMSE, FCAST3
C
C
C     INITIALIZATION
C
C
      SMALL=9999.9
      DO 5 I=1,12
        BS(I)=0.0
        DRATIO(I)=0.0
        SAR(I)=0.0
        ASAR(I)=0.0
        TREN(I)=0.0
        ERATIO(I)=0.0
        AERR(I)=0.0
        MAD(I)=0.0
        MSE(I)=0.0
 5    CONTINUE
C
      DO 7 J=1,30
        TAERR(J)=0.0
        TMAD(J)=0.0
        TMSE(J)=0.0
 7    CONTINUE
C
C     THIS LOOP COMPUTES THE BEST VALUE OF ALPHA BY
C     COMPARING THE TMAD AND TMSE ASSOCIATED WITH EACH
C     INDIVIDUAL ALPHA. THE BEST ALPHA CORRESPONDS TO
C     THE LOWEST TMSE AND TMAD. THE 2 ALPHAS ARE
C     AVERAGED TO YIELD THE BEST ALPHA.
C
        DO 10 I=1,12
          J=I+1
          K=I+2
          BS(I)=(BSDMD(I)+BSDMD(J)+BSDMD(K))/3
 10     CONTINUE
C
        DO 20 I=1,12
           DRATIO(I)=ADEMD(I)/BS(I)
 20     CONTINUE
C
      DO 150 L=1,30
          LNUM=L
          ALPHA(L)=LNUM/100.0
          ISAR=1.0
          DO 30 I=1,12
             SAR(I)=ALPHA(L)*DRATIO(I)+(1-ALPHA(L))*ISAR
             ISAR=SAR(I)
 30       CONTINUE
          I=1
          ASAR(I)=SAR(I)-0.0
          DO 40 I=2,12
             J=I-1
             ASAR(I)=SAR(I)-SAR(J)
 40      CONTINUE
C
          ITREND=0.0
          DO 50 I=1,12
             TREN(I)=(ALPHA(L)*ASAR(I))+(1-ALPHA(L))*
     &               ITREND
             ITREND=TREN(I)
 50     CONTINUE
C
        DO 60 I=1,12
           ERATIO(I)=SAR(I)+((1-ALPHA(L))/ALPHA(L))*
     &               TREN(I)
 60     CONTINUE
C
        DO 70 I=1,12
          K=I+1
          FCAST(K)=(ERATIO(I)+TREN(I))*BS(K)
70      CONTINUE
C
        DO 100 I=2,12
          AERR(I)=ADEMD(I)-FCAST(I)
          TAERR(L)=TAERR(L)+AERR(I)
          MAD(I)=ABS(AERR(I))
          TMAD(L)=TMAD(L)+MAD(I)
          MSE(I)=ABS(AERR(I))**2
          TMSE(L)=TMSE(L)+MSE(I)
          IF (TMAD(L).LT.SMALL) SMALL=TMAD(L)
          ALPHA1=ALPHA(L)
          IF (TMSE(L).LT.SMALL) SMALL=TMSE(L)
          ALPHA2=ALPHA(L)
 100    CONTINUE
          AALPHA=(ALPHA1+ALPHA2)/2
 150  CONTINUE
          ALFA=AALPHA
C
C
C     THIS LOOP COMPUTES THE SMOOTHED DEMAND (FORECASTS)
C     USING THE BEST ALPHA.
C
      DO 160 I=1,12
        J=I+1
        K=I+2
        BS(I)=(BSDMD(I)+BSDMD(J)+BSDMD(K))/3
 160  CONTINUE
C
      DO 170 I=1,12
        DRATIO(I)=ADEMD(I)/BS(I)
 170  CONTINUE
C
        ISAR=1.0
      DO 180 I=1,12
         SAR(I)=ALFA*DRATIO(I)+(1-ALFA)*ISAR
         ISAR=SAR(I)
 180  CONTINUE
C
      DO 190 I=1,12
        IF (I.EQ.1) ASAR(I)=SAR(I)-0.0
        J=I-1
        ASAR(I)=SAR(I)- SAR(J)
 190  CONTINUE
C
        ITREND=0.0
      DO 200 I=1,12
        TREN(I)=ALFA*ASAR(I)+(1-ALFA)*ITREND
        ITREND=TREN(I)
 200  CONTINUE
C
      DO 210 I=1,12
        ERATIO(I)=SAR(I)+((1-ALFA)/ALFA)*TREN(I)
 210  CONTINUE
C
      DO 220 I=1,12
        K=I+1
        FCAST3(K)=(ERATIO(I)+TREN(I))*BS(K)
        AERR(I)=ADEMD(I)-FCAST(I)
        CAERR=CAERR+AERR(I)
        MAD(I)=ABS(AERR(I))
        CMAD3=CMAD3+MAD(I)
        MSE(I)=ABS(AERR(I))**2
        CMSE=CMSE+MSE(I)
 220  CONTINUE
C
C     THIS LOOP EXTRAPOLATES THE SMOOTHED FORECASTS.
C
      DO 230 I=13,24
        K=I+1
        N=2
        FCAST3(K)=(SAR(12)+((1/ALFA)+N-1)*TREN(12))*BS(12)
        N=N+1
 230  CONTINUE
C
C
      RETURN
      END
C
C
C
C
      SUBROUTINE REPORT(ITYPE,DATE,FITEM,PERIOD,MORY)
C
C     ***************************************************
C     *  THIS ROUTINE OUTPUTS THE REPORT ACCORDINGLY.  *
C     ***************************************************
C
```

```
C
C
C     INPUT PARAMETER  : ITYPE,DATE,FITEM,PERIOD,MORY
C     OUTPUT PARAMETER : NONE
C
C
C
C     ITYPE  -  TYPE OF REPORT
C
      COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     *               FCAST1(25), FCAST2(25), FCAST3(25)
C
      REAL ADEMD, FCAST, BSDMD, FCAST1, FCAST2, FCAST3
C
      CHARACTER*8 DATE
      CHARACTER*40 FITEM,PERIOD
C
C TRANSFER FORECASTED DATA TO FCAST ARRAY FOR
C REPORT PRINTING AND GRAPH PLOTTING BY ROUTINE PLOT.
C
       GOTO (1,2,3) ITYPE
C
 1     DO 175 IBACK = 1,25
          FCAST(IBACK) = FCAST1(IBACK)
 175  CONTINUE
      GOTO 555
C
 2    DO 275 IBACK = 1,25
         FCAST(IBACK) = FCAST2(IBACK)
 275  CONTINUE
      GOTO 555
C
 3    DO 375 IBACK = 1,25
         FCAST9IBACK) = FCAST3(IBACK)
 375  CONTINUE
C
C PRINT REPORT HEADING
C
 555  WRITE(6,105) DATE
 105  FORMAT('0','ARGO ENGINEERING LIMITED',18X,
     &'DATE : ',A8,/,'0',/,'0')
C
      IF (MORY .EQ. 1) THEN
         WRITE(6,10)
 10      FORMAT('0',8X,'******* SHORT TERM FORECAST',
     &   'REPORT  *******')
         WRITE(6,12) FITEM,PERIOD
 12      FORMAT('0','ITEM - ',A40,/,
     &   'PERIOD - ',A40)
         WRITE(6,13)
 13      FORMAT('0',70('-'),/,
     &   ' ','MONTH NO.',11X,'ACTUAL',18X,'FORECAST',/,
     &   ' ',20X,'(UNITS)',17X,'(UNITS)'/,' ',70('-'))
      ELSE
```

```
            WRITE(6,11)
 11         FORMAT('0',8X'******* LONG TERM FORECAST',
     &      'REPORT  *******')
            WRITE(6,14) FITEM,PERIOD
 14         FORMAT('0','ITEM - ',A40,'PERIOD - ',A40)
            WRITE(6,15)
 15         FORMAT('0',70('-'),/,
     &      ' ','PERIOD NO.',10X,'ACTUAL',18X,'FORECAST',/,
     &      ' ',20X,'(UNITS)',17X,'(UNITS)',/,' ',70('-'))
         ENDIF
C
C PRINT FCAST DATA FOR FORECASTING REPORT
C
         DO 20 J = 1,12
            WRITE(6,21) J,ADEMD(J),FCAST(J)
 21         FORMAT(' ',I2,15X,F10.2,15X,F10.2)
 20      CONTINUE
C
         DO 30 J = 13,24
            IF (FCAST(J) .EQ. 0.0) GOTO 99
            WRITE(6,31) J,FCAST(J)
 31         FORMAT(' ',I2,25X,15X,F10.2)
 30      CONTINUE
C
C
 99      RETURN
         END
C
C
C
C
         SUBROUTINE PLOT
C
C        ***************************************************
C        *  THIS ROUTINE PLOTS THE EXPONENTIAL WEIGHTED    *
C        *  MOVING AVERAGE GRAPH ON THE LINE PRINTER.      *
C        ***************************************************
C
C
         COMMON /DATA1/ ADEMD(12), FCAST(25), BSDMD(14),
     *                  FCAST1(25), FCAST2(25), FCAST3(25)
C
         REAL ADEMD, FCAST, BSDMD, FCAST1, FCAST2, FCAST3
C
         CHARACTER*1 CHAR(60),JBLANK,JPLUS,JSTAR,JEQUAL
C
C INITIALISE PRINT CONSTANTS
C
         JBLANK = ' '
         JSTAR = 'A'
         JPLUS = '+'
         JEQUAL = 'F'
C
C INITIALISE PRINT LINE WITH BLANKS
```

```
C
      DO 400 I = 1,60
 400     CHAR(I) = JBLANK
C
C GET THE SMALLEST AND BIGGEST VALUE OF ACTUAL AND
C FORECASTED DATA.
C
      ASMALL = 999999.9
      FSMALL = 999999.9
      ABIG = 0.0
      FBIG = 0.0
C
      DO 10 I = 1,12
         IF (ADEMD(I) .LT. ASMALL) ASMALL = ADEMD(I)
         IF (ADEMD(I) .GT. ABIG) ABIG = ADEMD(I)
 10   CONTINUE
C
      DO 20 I = 1,25
         IF (FCAST(I) .LT. FSMALL) FSMALL = FCAST(I)
         IF (FCAST(I) .GT. FBIG) FBIG = FCAST(I)
20    CONTINUE
C
      SMALL = FSMALL
      BIG = FBIG
      IF (ASMALL .LT. FSMALL) SMALL = ASMALL
      IF (ABIG .GT. FBIG) BIG = ABIG
C
C
C FIND THE VALUE FOR THE X-AXIS DIVISIONS
C
      RANGE = (BIG - SMALL) + 1.0
      IDIV = (RANGE/10.0) + 0.5
C
C PRINT GRAPH HEADING
C
      WRITE (6,601)
 601  FORMAT ('1', 10X,/,
     &' EXPONENTIAL WEIGHTED MOVING AVERAGE GRAPH',/,10X,
     &' -----------------------------------------',/,10X
     &' ACTUAL DATA (AAAA)        FORECAST DATA  (FFFF)')
C
C
      ID1 = SMALL
      ID2 = SMALL + IDIV
      ID3 = SMALL + IDIV * 2
      ID4 = SMALL + IDIV * 3
      ID5 = SMALL + IDIV * 4
      ID6 = SMALL + IDIV * 5
      ID7 = SMALL + IDIV * 6
      ID8 = SMALL + IDIV * 7
      ID9 = SMALL + IDIV * 8
      ID10 = SMALL + IDIV * 9
C
C
```

```
      WRITE (6,602) ID1 , ID2, ID3, ID4,
     *ID5, ID6, ID7, ID8, ID9, ID10
  602 FORMAT (1X, 5X,10(I5))
C
      WRITE (6,603)
  603 FORMAT (1X, '         +', 9('----+'))
C
       MIN = 1.0
       MAX = 50.0
       DIFFMM = ((MAX - MIN)/(BIG - SMALL))
C
      DO 500 J = 1,12
         DO 22 I=1,60
            CHAR(I)=JBLANK
   22    CONTINUE
         IAVAL = (DIFFMM * (ADEMD(J) - SMALL)) + 1.0
         IFVAL = (DIFFMM * (FCAST(J) - SMALL)) + 1.0
         CHAR(IAVAL) = JSTAR
         CHAR(IFVAL) = JEQUAL
         IF (MOD(J,5)) 100,501,100
  501        DO 530 K = 5,50,5
  530           CHAR(K) = JPLUS
  100        WRITE(6,604) J, CHAR
  604        FORMAT(1X,I5,60A1)
  500 CONTINUE
C
      DO 550 JCOUNT = 1,12
         J = JCOUNT + 12
         DO 23 I = 1,60
            CHAR(I) = JBLANK
   23    CONTINUE
         IFVAL = (DIFFMM * (FCAST(J) - SMALL)) + 1.0
         CHAR(IFVAL) = JEQUAL
         IF (MOD(J,5)) 201,502,201
  502        DO 531 K = 5,50,5
  531           CHAR(K) = JPLUS
  201        WRITE(6,605) J, CHAR
  605        FORMAT(1X, I5, 60A1)
  550 CONTINUE
C
C
      RETURN
      END
```

```
$TITLE:'MSc. THESIS PROGRAM - 2'
$SUBTITLE:'MASTER PRODUCTION SCHEDULE MODEL'
      PROGRAM MPSM
C
C     *************************************************
C     * THIS IS THE MAIN PROGRAM OF THE MPS MODEL.    *
C     * THIS PROGRAM PRODUCES THREE TYPES OF REPORTS. *
C     *************************************************
C
      COMMON /DAT/ GROSSF(20),BKINGS(20),NETF(20),
     &             NETREQ(20),BKLOG(20),GROSSR(20),
     &             SOHAND(20),MPS(20),AWEEK(20),EOQ,ROL
C
      CHARACTER*1 PARTNO(10),DESCRP(40),MORB,CLASS,DATES*8
C
      INTEGER LTCODE,MLT,JLSIZE,PLT,ORDQTY,MINQTY,MAXQTY,
     &        SHRINK,HORZON,NWEEK
      INTEGER GROSSF,BKINGS,NETF,NETREQ,BKLOG,GROSSR,
     &        SOHAND,MPS,AWEEK,EOQ,ROL
C
C OPEN OUTPUT FILE
C
      OPEN (6,FILE='PRN')
C
C REQUEST USER TO INPUT DATA FOR END ITEM FILE REPORT
C
      WRITE(*,388)
 388  FORMAT(' ',38('*'),/,
     &' ','*  MASTER PRODUCTION SCHEDULE MODEL  *',/,
     &' ',38('*'),/,' ')
C
      WRITE(*,399)
 399  FORMAT(' ','ENTER TODAY"S DATE (MM/DD/YY):')
      READ(*,499) DATE
 499  FORMAT(BN,A8)
C
      WRITE(*,501)
 501  FORMAT(' ','ENTER PART NUMBER',
     &    ' (10 ALPHANUMERIC VALUE):')
      READ(*,502) (PARTNO(I),I=1,10)
 502  FORMAT(10A1)
C
      WRITE(*,503)
 503  FORMAT(' ','ENTER DESCRIPTION',
     &    ' (40 ALPHANUMERIC VALUE):')
      READ(*,504) (DESCRP(I),I=1,40)
 504  FORMAT(40A1)
C
      WRITE(*,505)
 505  FORMAT(' ','ENTER MAKE/BUY (M/B):')
      READ(*,506) MORB
 506  FORMAT(A1)
C
      WRITE(*,507)
 507  FORMAT(' ','ENTER CLASSIFICATION (A/B/C):')
      READ(*,508) CLASS
 508  FORMAT(A1)
C
      WRITE(*,509)
 509  FORMAT(' ','ENTER LEAD TIME CODE (1 DIGIT):')
      READ(*,510) LTCODE
 510  FORMAT(I1)
C
      WRITE(*,511)
 511  FORMAT(' ','ENTER MANUFACTURING LEAD TIME (1 DIGIT):')
      READ(*,512) MLT
 512  FORMAT(I3)
C
      WRITE(*,513)
 513  FORMAT(' ','ENTER JOB LOT SIZE (4 DIGITS):')
      READ(*,514) JLSIZE
 514  FORMAT(I4)
C
      WRITE(*,515)
 515  FORMAT(' ','ENTER PURCHASE LEAD TIME (3 DIGITS):')
      READ(*,516) PLT
 516  FORMAT(I3)
C
      WRITE(*,517)
 517  FORMAT(' ','ENTER PURCHASE ORDER QUANTITY',
     &'(5 DIGITS):')
      READ(*,518) ORDQTY
 518  FORMAT(I5)
C
      WRITE(*,519)
 519  FORMAT(' ','ENTER MINIMUM QUANTITY',
     &'(5 DIGITS):')
      READ(*,520) MINQTY
 520  FORMAT(I5)
C
      WRITE(*,521)
 521  FORMAT(' ','ENTER MAXIMUM QUANTITY',
     &'(5 DIGITS):')
      READ(*,522) MAXQTY
 522  FORMAT(I5)
C
      WRITE(*,523)
 523  FORMAT(' ','ENTER SCRAP (4 DIGITS):')
      READ(*,524) SHRINK
 524  FORMAT(I4)
C
      WRITE(*,525)
 525  FORMAT(' ','ENTER HORIZON (3 DIGITS):')
      READ(*,526) HORIZON
 526  FORMAT(I3)
C
C **************** END OF 1ST DATA INPUT ****************
C
```

```
      WRITE(*,333)
  333 FORMAT(' ','**** PRINTING .......')
C
C PRINT END ITEM FILE REPORT
C
      WRITE(6,301) DATE
  301 FORMAT('1','ARGO ENGINEERING LIMITED',35X,
     &'DATE :',A8,/,'0',/,'0')
      WRITE(6,401)
  401 FORMAT(' ',20X,'*****  END ITEM FILE REPORT',
     &' *****',/,'0',/,' ')
      WRITE(6,402) (PARTNO(I),I=1,10)
  402 FORMAT(' ','PART NUMBER',26X,'-',10A1)
      WRITE(6,403) (DESCRP(I),I=1,40)
  403 FORMAT(' ','DESCRIPTION',26X,'-',40A1)
      WRITE(6,404) MORB
  404 FORMAT(' ','MAKE/BUY (M/B)',23X,'-',A1)
      WRITE(6,405) CLASS
  405 FORMAT(' ','CLASSIFICATION (A/B/C)',15X,'-',A1)
      WRITE(6,406) LTCODE
  406 FORMAT(' ','LEAD TIME CODE (1/2/3)',15X,' - ',I1)
      WRITE(6,677) MLT
  677 FORMAT(' ','MANUFACTURING LEAD TIME (DAYS)',7X,
     &' - ',I5)
      WRITE(6,407) JLSIZE
  407 FORMAT(' ','JOB LOT SIZE (UNITS)',17X,' - ',I5)
      WRITE(6,408) PLT
  408 FORMAT(' ','PURCHASE LEAD TIME (DAYS)',12X,' - ',I5)
      WRITE(6,409) ORDQTY
  409 FORMAT(' ','PURCHASE ORDER QUANTITY (UNITS)',6X,
     &' - ',I5)
      WRITE(6,410) MINQTY
  410 FORMAT(' ','MINIMUM QUANTITY (UNITS)',13X,' - ',I5)
      WRITE(6,411) MAXQTY
  411 FORMAT(' ','MAXIMUM QUANTITY (UNITS)',13X,' - ',I5)
      WRITE(6,412) SHRINK
  412 FORMAT(' ','SCRAP (%)',28X,'-',I4)
C
C CALL SUBROUTINE INIT,MPSR,MPSRL
C
      CALL INIT
      CALL MPSR (NWEEK,IPW)
      CALL MPSRL (NWEEK,SHRINK,IPW)
C
      END
C
C
C
C
      SUBROUTINE MPSR (NWEEK,IPW)
C
C     ************************************
C     * THIS IS A SUBROUTINE OF MPSM.    *
C     * THIS ROUTINE PRODUCES THE MASTER *
```

```
C     * PRODUCTION SCHEDULE REPORT.        *
C     ************************************
C
C     INPUT PARAMETER   : NWEEK,IPW
C     OUTPUT PARAMTER   : NONE
C
C
C
      COMMON /DAT/ GROSSF(20),BKINGS(20),NETF(20),
     &             NETREQ(20),BKLOG(20),GROSSR(20),
     &             SOHAND(20),MPS(20),AWEEK(20),EOQ,ROL
C
      INTEGER GROSSF,BKINGS,NETF,NETREQ,BKLOG,GROSSR,
     &        SOHAND,MPS,AWEEK,EOQ,ROL
C
      CHARACTER*1 CHAR
C
C REQUEST USER TO INPUT DATA FOR MASTER PRODUCTION
C SCHEDULE REPORT.
C
      WRITE(*,1)
 1    FORMAT('0','**** ENTER DATA FOR MASTER
     &' PRODUCTION SCHEDULE REPORT ****')
      WRITE(*,341)
 341  FORMAT('0','ENTER LONG/SHORT TERM',/,
     &' ','PRESS 1 FOR LONG TERM',/,
     &' ','PRESS 2 FOR SHORT TERM')
      READ(*,341) LS
 341  FORMAT(I1)
C
      WRITE(*,330)
 330  FORMAT(' ','ENTER PERIOD/WEEK'/,
     &' ','PRESS 1 FOR PERIOD',/,
     &' ','PRESS 2 FOR WEEK')
      READ(*340) IPW
 340  FORMAT(I1)
C
C PRINT HORIZON IN END ITEM REPORT
C
      IF (IPW .EQ. 1) THEN
          WRITE(6,413) HORZON
 413      FORMAT(' ','HORIZON (PERIODS)',10X,' - ',I5)
      ELSE
          WRITE(6,414) HORZON
 414      FORMAT(' ','HORIZON (MONTHS)',11X,' - ',I5)
      ENDIF
C
C
      WRITE(*,2)
 2    FORMAT(' ','ENTER NUMBER OF WEEKS/PERIOD DESIRED',
     &'(2 DIGITS) :')
      READ(*,3) IWEEK
 3    FORMAT(I2)
      WRITE(*,4)
 4    FORMAT(' ','ENTER BEGINNING WEEK NO./PERIOD NO.',
     &'(2 DIGITS):')
      READ(*,5) AWEEK(1)
 5    FORMAT(I2)
C
      WRITE(*,10)
 10   FORMAT(' ','ENTER ECONOMIC ORDER QUANTITY',
     &'(4 DIGITS):')
      READ(*,11) EOQ
 11   FORMAT(I4)
C
      WRITE(*,12)
 12   FORMAT(' ','ENTER REORDER LEVEL (4 DIGITS):')
      READ(*,13) ROL
 13   FORMAT(I4)
C
      WRITE(*,90)
 90   FORMAT(' ','ENTER BACKLOG AND STOCK ON HAND',
     &' FOR THE 1ST WEEK',
     &'(2 DIGITS FOLLOWED BY 2 DIGITS):')
      READ(*,102) BKLOG(1),CHAR,SOHAND(1)
 102  FORMAT(I2,A1,I2)
C
      WRITE(*,103)
 103  FORMAT(' ','ENTER GROSS FORECAST AND BOOKINGS',
     &' FOR THOSE WEEKS/PERIODS DESIRED',
     &'(5 DIGITS FOLLOWED BY 5 DIGITS):')
C
      DO 105 J = 1,IWEEK
         READ(*,106) GROSSF(J),CHAR,BKINGS(J)
 106     FORMAT(I5,A1,I5)
 105  CONTINUE
C
      WRITE(*,88)
 88   FORMAT(' ','**** PRINTING......')
C
C CALL SUBROUTINE SRPORT
C
      CALL SRPORT (IWEEK)
C
      IF (LS .EQ. 1) THEN
         WRITE(6,600)
 600     FORMAT('0',/,'0',/,' ',10X,'**** LONG TERM',
     &' MASTER PRODUCTION SCHEDULE REPORT ****',/,'0')
      ELSE
         WRITE(6,602)
 602     FORMAT('0',/,'0',/,' ',10X,'**** SHORT TERM',
     &' MASTER PRODUCTION SCHEDULE REPORT ****',/,'0')
      ENDIF
C
      N = 0
C
      WRITE(6,501)
 501  FORMAT(' ',80('-'))
```

```
C
      IF (IPW .EQ. 1) THEN
         WRITE(6,410) EOQ
 410     FORMAT('0','EOQ = ',I4,10X,5('PERIOD NO. '))
      ELSE
         WRITE(6,601) EOQ
 601     FORMAT('0',EOQ = ',I4,10X,5('  WEEK NO.  '))
      ENDIF
C
      WRITE(6,580) ROL,(AWEEK(I),I=1,5)
 508  FORMAT(' ','ROL = ',I4,13X,4(I4,8X),I4)
      WRITE(6,502)
 502  FORMAT(' ',80('-'))
C
      WRITE(6,603) (GROSSF(I),I=1,5)
 603  FORMAT(' ','GROSS FORECAST',6X,5(I7,5X))
      WRITE(6,604) (BKINGS(I),I=1,5)
 604  FORMAT(' ','BOOKINGS',12X,5(I7,5X))
      WRITE(6,605) (NETF(I),I=1,5)
 605  FORMAT(' ','NET FORECAST',8X,5(I7,5X))
      WRITE(6,606) (BKLOG(I),I=1,5)
 606  FORMAT(' ','BACKLOG',13X,5(I7,5X))
      WRITE(6,300) (NETREQ(I),I=1,5)
 300  FORMAT(' ','NET REQUIREMENTS',4X,5(I7,5X))
      WRITE(6,607) (GROSSR(I),I=1,5)
 607  FORMAT(' ','GROSS REQUIREMENTS',2X,5(I7,5X))
      WRITE(6,608) (SOHAND(I),I=1,5)
 608  FORMAT(' ','STOCK ON HAND',7X,5(I7,5X))
      WRITE(6,609) (MPS(I),I=1,5)
 609  FORMAT(' ','MPS',17X,5(I7,5X))
C
      NUMWK = IWEEK
      M = 4 + AWEEK(I)
      N = 5
C
 400  NUMWK = NUMWK - 5
      IF (NUMWK .GT. 0) THEN
         M = M + 1
         N = N + 1
         IF (IPW .EQ. 1) THEN
            WRITE(6,420) EOQ
 420        FORMAT('0',80('-'),/,' ','EOQ = ',I4,10X,
     &             5('PERIOD NO.  '))
         ELSE
            WRITE(6,610) EOQ
 610        FORMAT('0',80('-'),/,' ',EOQ = ',I4,10X,
     &             5('  WEEK NO.  '))
         ENDIF
C
         DO 611 I = N,N+4
            WRITE(6,612) ROL,M,M+1,M+2,M+3,M+4
 612        FORMAT(' ','ROL = ',I4,13X,4(I4,8X),I4)
            WRITE(6,550)
 550        FORMAT(' ',80('-'))
```

```
            WRITE(6,613) (GROSSF(I),I=N,N+4)
 613        FORMAT(' ','GROSS FORECAST',6X,5(I7,5X))
            WRITE(6,614) (BKINGS(I),I=N,N+4)
 614        FORMAT(' ','BOOKINGS',12X,5(I7,5X))
            WRITE(6,615) (NETF(I),I=1,N,N+4)
 615        FORMAT(' ','NET FORECAST',8X,5(I7,5X))
            WRITE(6,616) (BKLOG(I),I=N,N+4)
 616        FORMAT(' ','BACKLOG',13X,5(I7,5X))
            WRITE(6,310) (NETREQ(I),I=N,N+4
 310        FORMAT(' ','NET REQUIREMENTS',4X,5(I7,5X))
            WRITE(6,617) (GROSSR(I),I=N,N+4)
 617        FORMAT(' ','GROSS REQUIREMENTS',2X,5(I7,5X))
            WRITE(6,618) (SOHAND(I),I=N,N+4)
 618        FORMAT(' ','STOCK ON HAND',7X,5(I7,5X))
            WRITE(6,619) (MPS(I),I=N,N+4)
 619        FORMAT(' ','MPS',17X,5(I7,5X))
C
 611     CONTINUE
       M = M + 4
       N = N + 4
       GOTO 400
       ENDIF
C
       RETURN
       END
C
C
C
C
      SUBROUTINE MPSRL(IWK,ISHRNK,IPW)
C
C     ***************************************************
C     * THIS IS A SUBROUTINE OF MPSM.                   *
C     * THIS ROUTINE PRODUCES THE RECEIPT LIST REPORT.*
C     ***************************************************
C
C
C     INPUT PARAMETER  : IWK,ISHRNK,IPW
C     OUTPUT PARAMETER : NONE
C
C
      COMMON /DAT/ GROSSF(20),BKINGS(20),NETF(20),
     &             NETREQ(20),BKLOG(20),GROSSR(20),
     &             SOHAND(20),MPS(20),AWEEK(20),EOQ,ROL
C
      INTEGER IWK,SHRNK,IPW
      INTEGER GROSSF,BKINGS,NETF,NETREQ,BKLOG,GROSSR,
     &        SOHAND,MPS,AWEEK,EOQ,ROL
C
      REAL SCRAP
C
C PRINT RECEIPT LIST REPORT HEADING
C
      WRITE(6,10)
 10   FORMAT('0',/,'0',/,'0',20X,'**** RECEIPT LIST',
     &' REPORT ****',/,'0')
      WRITE(6,11)
 11   FORMAT(' ',20X,31('-'))
C
      IF (IPQ .EQ. 1) THEN
          WRITE(6,222)
 222      FORMAT(' ',20X,'PERIOD NO',3X,'QUANTITY',5X,
     &    'SCRAP',/,' ',33X,'(UNITS)',5X,'(UNITS)',/,
     &    21X,31('-'))
      ELSE
          WRITE(6,12)
 12       FORMAT(' ',20X,'WEEK NO',5X,'QUANTITY',5X,
     &    'SCRAP',/,33X,'(UNITS)',5X,'(UNITS)',/,
     &    21X,31('-'))
      ENDIF
C
C CALCULATE SCRAP VALUE
C
      DO 100 I = 1,IWK
         IF (MPS(I) .NE. 0) THEN
             SCRAP = (ISHRNK/100.0) * MPS(I)
             WRITE(6,601) AWEEK(I),MPS(I),SCRAP
 601         FORMAT(' ',20X,I6,4X,I6,3X,F10.2)
         ENDIF
 100  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE SRPORT (IWEEK)
C
C     *************************************************
C     * THIS IS A SUBROUTINE OF MPSM.                 *
C     * THIS ROUTINE DOES THE NECESSARY CALCULATIONS *
C     * FOR PRODUCING THE MASTER PRODUCTION SCHEDULE *
C     * REPORT.                                       *
C     *************************************************
C
C
C     INPUT PARAMETER  : IWEEK
C     OUTPUT PARAMETER : NONE
C
C
      COMMON /DAT/ GROSSF(20),BKINGS(20),NETF(20),
     &             NETREQ(20),BKLOG(20),GROSSR(20),
     &             SOHAND(20),MPS(20),AWEEK(20),EOQ,ROL
C
      INTEGER GROSSF,BKINGS,NETF,NETREQ,BKLOG,GROSSR,
     &        SOHAND,MPS,AWEEK,EOQ,ROL
C
```

```
C CALCULATIONS FOR MASTER PRODUCTION SCHEDULE REPORT.
C
      DO 200 K = 1,IWEEK
         NETF(K) = GROSS(K) - BKINGS(K)
         IF (GROSSF(K) .GE. BKINGS(K)) THEN
             NETREQ(K) = GROSSF(K)
         ELSE
             NETREQ(K) = BKINGS(K)
         ENDIF
C
         IF (K .EQ. 1) THEN
            AWEEK(K) = AWEEK(1)
            BKLOG(K) = BKLOG(1)
            SOHAND(K) = SOHAND(1)
            GROSSR(K) = NETREQ(1) + BKLOG(1)
         ELSE
            AWEEK(K) = AWEEK(1)+(K-1)
            BKLOG(K) = 0
            GROSSR(K) = NETREQ(K)
            SOHAND(K) = SOHAND(K)
         ENDIF
C
         SOHAND(K+1) = SOHAND(K) - GROSSR(K)
         IF (SOHAND(K+1) .GE. ROL) THEN
            MPS(K) = 0
         ELSE
            IF (SOHAND(K+1) .LT. ROL) THEN
               EOQ = 0 - EOQ
               IF (SOHAND(K+1) .GE. EOQ) THEN
                  MPS(K) = IABS(EOQ)
               ELSE
                  IF (SOHAND(K+1) .LT. EOQ) THEN
                     DO 210 M = 1,100
                        IF (SOHAND(K+1) .GE. EOQ*(M+1))
      &                 THEN
                            MPS(K) = IABS(EOQ*(M+1))
                            GOTO 220
                        ENDIF
 210                 CONTINUE
                  ENDIF
               ENDIF
 220           SOHAND(K+1) = SOHAND(K)+MPS(K)-GROSSR(K)
            ENDIF
         ENDIF
         EOQ = IABS(EOQ)
 200  CONTINUE
C
      RETURN
      END
C
C
C
C
       SUBROUTINE INIT
```

```
C
C     ********************************************
C     * THIS ROUTINE INITIALISES DATA FOR THE    *
C     * MPSM.                                    *
C     ********************************************
C
      COMMON /DAT/ GROSSF(20),BKINGS(20),NETF(20),
     &             NETREQ(20),BKLOG(20),GROSSR(20),
     &             SOHAND(20),MPS(20),AWEEK(20),EOQ,ROL
C
      INTEGER GROSSF,BKINGS,NETF,NETREQ,BKLOG,GROSSR,
     &        SOHAND,MPS,AWEEK,EOQ,ROL
C
C INITIALISATION
C
      DO 100 I = 1,20
         GROSSF(I) = 0
         BKINGS(I) = 0
         NETF(I) = 0
         NETREQ(I) = 0
         BKLOG(I) = 0
         SOHAND(I) = 0
         MPS(I) = 0
         AWEEK(I) = 0
 100  CONTINUE
C
      RETURN
      END
```

```
$TITLE:'MSc. THESIS PROGRAM - 3'
$SUBTITLE:'RESOURCE REQUIREMENTS PLANNING MODEL'
      PROGRAM RRPM
C
C     ********************************************
C     * THIS IS THE MAIN PROGRAM OF THE          *
C     * RESOURCE REQUIREMENTS PLANNING MODEL.    *
C     ********************************************
C
      COMMON /INP/ NYRS,IYEAR
C
      COMMON /PQTY1/ PRODCD(100)
      COMMON /PQTY2/ PRODQT(100,10), NOPROD
C
      COMMON /CA1/ DEPTCD(600), MORD(600)
      COMMON /CA2/ NDEPT, MCAP(600)
C
      COMMON /CREQ1/ PCODE(100), DCODE(100,600)
      COMMON /CREQ2/ STDHR(100,600)
C
      INTEGER PRODQT,STDHR
C
      CHARACTER*1 PRODCD*10,PCODE*10,DEPTCD*4,DCODE*4,
     &            MORD(600),DATE*8
C
C OPEN OUTPUT FILE
C
      OPEN (6,FILE='PRN')
C
C REQUEST USER TO INPUT DATA
C
      WRITE(*,888)
 888  FORMAT(' ',42('*'),/,
     &' ','*  RESOURCE REQUIREMENTS PLANNING MODEL  *',
     &/,' ',42('*'),/,' ')
C
      WRITE(*,1)
 1    FORMAT(' ','ENTER TODAY"S DATE (MM/DD/YY):')
      READ(*,2) DATE
 2    FORMAT(BN,A8)
C
      WRITE(*,10)
 10   FORMAT(' ','ENTER NUMBER OF YEARS TO BE',
     &' PROCESSED (2 DIGITS):')
      READ(*,11) NYRS
 11   FORMAT(BN,I2)
      WRITE(*,13) IYEAR
 13   FORMAT(BN,I4)
C
      N = NYRS*2
C
C OPEN INPUT FILES
C
      OPEN (1,FILE='PQTYFL')
      OPEN (2,FILE='CAVAILFL')
      OPEN (3,FILE='CREQFL')
C
C READ INPUT FILES AND STORE INFORMATION IN
C COMMON BLOCK AREA; /PQTY/, /CA/ AND /CREQ/
C RESPECTIVELY.
C
C READ FILE PQTYFL
C
      READ(1,14) NOPROD
 14   FORMAT(I4)
C
      DO 100 I = 1,NOPROD
         READ(1,15) PRODCD(I)
 15      FORMAT(A10)
         READ(1,16) (PRODQT(I,K),K=1,N)
 16      FORMAT(I5,9I6)
 100  CONTINUE
C
C READ FILE CAVAILFL
C
      READ(2,20) NDEPT
 20   FORMAT(I4)
      DO 200 I = 1,NDEPT
         READ(2,21) DEPTCD(I),MCAP(I),MORD(I)
 21      FORMAT(A4,I7,A2)
 200  CONTINUE
C
C READ FILE CREQFL
C
      DO 300 I = 1,NOPROD
         READ(3,30) PCODE(I)
 30      FORMAT(A10)
         DO 350 J = 1,NDEPT
            READ(3,31) DCODE(I,J),STDHR(I,J)
 31         FORMAT(A5,I5)
 350     CONTINUE
 300  CONTINUE
C
C CALL SUBROUTINES RRPCAL,RRPR1 & RRPSR1
C
      CALL RRPCAL
      CALL RRPR1 (DATE,INEG)
      IF (INEG .GT. 0) THEN
         CALL RRPSR1
      ENDIF
C
      END
C
C
C
C
      SUBROUTINE RRPCAL
C
```

```
C     ***************************************************
C     * THIS ROUTINE DOES THE NECCESSARY CALCULATIONS  *
C     * FOR PRODUCING THE LONG TERM WORK CENTER         *
C     * LOAD REPORT.                                    *
C     ***************************************************
C
C
C     INPUT PARAMETER   : NONE
C     OUTPUT PARAMTER   : NONE
C
C
C
      COMMON /INP/ NYRS,IYEAR
C
      COMMON /PQTY1/ PRODCD(100)
      COMMON /PQTY2/ PRODQT(100,10),NOPROD
C
      COMMON /CA2/ NDEPT,MCAP(600)
C
      COMMON /CREQ2/ STDHR(100,600)
C
      COMMON /CNEED1/ CPNEED(600),CPAVAL(600),
     &                HRAVAL(4000),TOTCAP(600,10)
C
      INTEGER PRODQT,STDHR,CPNEED,CPAVAL,HRAVAL,TOTCAP
C
      CHARACTER*1 PRODCD*10
C
C INITIALISATION
C
      DO 10 I = 1,20
         DO 20 J = 1,10
            TOTCAP(I,J) = 0
 20      CONTINUE
 10   CONTINUE
C
C COMPUTATION FOR TOTAL CAPACITY
C
      MAX = 2*NYRS
      DO 100 I = 1,MAX
         DO 150 K = 1,NOPROD
            DO 200 J = 1,NDEPT
C
C              CHECK STDHR OF RIGHT PRODUCT CODE
C
               DO 201 L = 1,NOPROD
                  IF (PRODCD(K) .EQ. PCODE(L)) THEN
                     GOTO 202
                  ENDIF
 201           CONTINUE
 202           CPNEED(J) = PRODQT(K,I)*STDHR(K,J)
 200        CONTINUE
            DO 220 N = 1,NDEPT
               TOPTCAP(N,I) = TOTCAP(N,I)+CPNEED(N)
 220        CONTINUE
 150     CONTINUE
C
 100  CONTINUE
C
C COMPUTATION FOR MACHINE HOURS AVAILABLE
C
      DO 310 J = 1,NDEPT
         CPAVAL(J) = MCAP(J)*130
 310  CONTINUE
C
      JSUB = 1
      IHALF = 1
      DO 400 I = 1,NYRS
         DO 410 J = 1,NDEPT
            HRAVAL(JSUB) = CPAVAL(J)-TOTCAP(J,IHALF)
            HRAVAL(JSUB+1) = CPAVAL(J)-TOTCAP(J,IHALF+1)
            JSUB = JSUB + 2
 410     CONTINUE
      IHALF = IHALF + 2
 400  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE RRPR1 (DATE,INEG)
C
C     ***********************************************
C     * THIS ROUTINE PRODUCES THE REPORT FOR THE    *
C     * LONG TERM WORK CENTER LOAD REPORT.          *
C     ***********************************************
C
C
C     INPUT PARAMETER  : DATE
C     OUTPUT PARAMETER : INEG
C
C
      COMMON /INP/ NYRS,IYEAR
C
      COMMON /CA2/ NDEPT,MCAP(600)
C
      COMMON /CNEED1/ CPNEED(600),CPAVAL(600),
     &               HRAVAL(4000),TOTCAP(600,10)
C
      COMMON /OVER1/ JYEAR(99),JYHALF(99),JVALUE(99)
     &               NEG
C
      CHARACTER*8 DATE
C
      INTEGER CPNEED,CPAVAL,HRAVAL,TOTCAP
C
```

```
C
C PRINT REPORT HEADING
C
      NYEAR = IYEAR - 1
      ITOT = 1
      NEG = 0
      N = 1
C
      WRITE(6,90) DATE
 90   FORMAT('0','ARGO ENGINEERING LIMITED',35X,
     &' DATE :',A8,/,'0',/,'0')
      WRITE(6,101)
 101  FORMAT('0',15X,'**** LONG TERM WORK CENTER LOAD',
     &' REPORT ****',/,' ')
C
      DO 200 I = 1,NYRS
         WRITE(6,102)
 102     FORMAT('0',80('-'),/,' ',6X,11X,'1',23X,'2',
     &12X,8X,'3 = 2 - 1',7X,/,80('-'))
         WRITE(6,103) NYEAR+I
 103     FORMAT(' ',1X,'DEPT ',1X,'M/C',3X,
     &   'PROJECTED STD.',4X,4X,

     &   'STD. HRS AVAILABLE',2X,6X,'AVAILABLE STD.',
     &2X,/,' ',6X,5X,'HRS FOR ',4X,5X,4X,
     &' AT PRESENT CAPACITY',15X,'HOURS')
         WRITE(6,104)
 104     FORMAT(' ',80('-'),/,' ',10X,
     &   2('[1ST HALF] [2ND HALF]  '),
     &   '[1ST HALF] [2ND HALF]')
C
         DO 300 J = 1,NDEPT
            IF (HRAVAL(N) .LT. 0) THEN
               IF (HRAVAL(N+1) .LT. 0) THEN
                  CALL RRPPRT(1,J,ITOT,NYEAR+I)
               ELSE
                  CALL RRPPRT(2,J,ITOT,NYEAR+I)
               ENDIF
            ELSE
               IF (HRAVAL(N+1) .LT. 0) THEN
                  CALL RRPPRT(3,J,ITOT,NYEAR+I)
               ELSE
                  CALL RRPPRT(4,J,ITOT,NYEAR+I)
               ENDIF
            ENDIF
         N = N + 4
 300  CONTINUE
      ITOT = ITOT + 2
 200  CONTINUE
C
      INEG = NEG
      RETURN
      END
C
```

```
C
       SUBROUTINE RRPSR1
C
C      **********************************************
C      * THIS ROUTINE PRODUCES THE OVERLOAD REPORT. *
C      **********************************************
C
C
      COMMON /OVER1/ JYEAR(99),JHALF(99),JVALUE(99),
     &               NEG
      COMMON /OVER2/ JDEPT(99)
C
      CHARACTER*1 JDEPT*4
C
C PRINT OVERLOAD REPORT
C
3     WRITE(6,201)
 201  FORMAT('0',/,'0',20X.'**** OVERLOAD REPORT ',
     &'****',/,'0',80('-'),/,' ',15X,'DEPT        ',
     &3X,'YEAR   ',6X,'OVERLOAD (STD.HRS)',/,' ',
     &80('-'))
C
      DO 202 I = 1,NEG
         WRITE(6,203) JDEPT(I),JYEAR(I),JHALF(I),
     &                JVALUE(I)
 203    FORMAT(' ',15X,A3,9X,I4,' (',I1,')',10X,I8)
 202  CONTINUE
C
 99   RETURN
      END
C
C
C
      SUBROUTINE RRPRPT (ITYPE,J,I,N,IYRVAL)
C
C     *************************************************
C     * THIS ROUTINE PRODUCES THE REPORT FOR THE      *
C     * LONG TERM WORK CENTER LOAD REPORT.            *
C     *************************************************
C
C
      INPUT PARAMETER  : ITYPE,J,I,N,IYRVAL
      OUTPUT PARAMETER : NONE
C
C
C     ITYPE  - TYPE OF OUTPUT
C     J      - DEPT.CODE
C     I      - YEAR NUMBER
C     N      - 1ST HALF/2ND HALF
C     IYRVAL - YEAR
C
      COMMON /CNEED1/ CPNEED(600),CPAVAL(600),
     &              HRAVAL(4000),TOTCAP(600,10)
C
```

```
      COMMON /OVER1/ JYEAR(99),JYHALF(99),JVALUE(99),
     &               NEG
      COMMON /OVER2/ JDEPT(99)
C
      COMMON /CA1/ DEPTCD(600),MORD(600)
C
      INTEGER CPNEED,CPAVAL,HRAVAL,TOTCAP
C
      CHARACTER*1 DEPTCD*4,JDEPT*4,MORD
C
      IF (MORD(J) .EQ. 'D') THEN
         WRITE(6,105) DEPTCD(J),TOTCAP(J,I),TOTCAP(J,I+1),
     &   CPAVAL(J),CPAVAL(J),HRAVAL(N),HRAVAL(N+1)
 105     FORMAT(' ',A4,5X,6(2X,I8,2X))
      ELSE
         IF (MORD(J) .EQ. 'M') THEN
             WRITE(6,106) DEPTCD(J),TOTCAP(J,I),
     &        TOTCAP(J,I+1),CPAVAL(J),CPAVAL(J),
     &        HRAVAL(N),HRAVAL(N+1)
 106         FORMAT(' ',5X,A4,6(2X,I8,2X))
         ENDIF
      ENDIF
C
      GOTO (1,2,3,99) ITYPE
C
 1    NEG = NEG + 1
      JDEPT(NEG) = DEPTCD(J)
      JYEAR(NEG) = IYRVAL
      JHALF(NEG) = 1
      JVALUE(NEG) = HRAVAL(N)
      NEG = NEG + 1
      JDEPT(NEG) = DEPTCD(J)
      JYEAR(NEG) = IYRVAL
      JHALF(NEG) = 2
      JVALUE(NEG) = HRAVAL(N+1)
      GOTO 99
C
 2    NEG = NEG + 1
      JDEPT(NEG) = DEPTCD(J)
      JYEAR(NEG) = IYRVAL
      JHALF(NEG) = 1
      JVALUE(NEG) = HRAVAL(N)
      GOTO 99
C
 3    NEG = NEG + 1
      JDEPT(NEG) = DEPTCD(J)
      JYEAR(NEG) = IYRVAL
      JHALF(NEG) = 2
      JVALUE(NEG) = HRAVAL(N)
      GOTO 99
C
C
 99   RETURN
      END
```

```
$TITLE:'MSc. THESIS PROGRAM - 4'
$SUBTITLE:'CAPACITY REQUIREMENTS PLANNING MODEL'
      PROGRAM CRPM
C
C     ********************************************
C     * THIS IS THE MAIN PROGRAM OF THE CRP MODEL  *
C     * I.E. CAPACITY REQUIREMENTS PLANNING MODEL. *
C     ********************************************
C
      COMMON /USER1/ NUMCP,STDATE(50),CPAMT(50)
      COMMON /USER2/ CPNENT(50)
C
      INTEGER DAY,MONTH,YEAR,MONDAY,PCDAYN,STDATE,CPAMT
C
      CHARACTER*1 A,B,CPNENT*10
C
C REQUEST USER TO INPUT TODAY'S DATE
C
      WRITE(*,1)
 1    FORMAT(' ',42('*'),/,
     &' ','*  CAPACITY REQUIREMENTS PLANNING MODEL  *',/,
     &' ',42('*'))
C
      WRITE(*,10)
 10   FORMAT(' ','ENTER TODAY'S DATE (MM/DD/YY):')
      READ(*,11) MONTH,A,DAY,B,YEAR
 11   FORMAT(I2,A1,I2,A1,I2)
C
      WRITE(*,20)
 20   FORMAT(' ','ENTER PRODUCTION CALENDER DAY NUMBER',
     &' (3 DIGITS):')
      READ(*,21) PCDAYN
 21   FORMAT(BN,I3)
C
      WRITE(*,22)
 22   FORMAT(' ','ENTER 1ST DAY OF WEEK NUMBER',
     &' (3 DIGITS):')
      READ(*,23) MONDAY
 23   FORMAT(BN,I3)
C
C READ INPUT DATA
C
      WRITE(*,25)
 25   FORMAT(' ','ENTER #COMPONENTS TO BE PROCESSED',
     &' (3 DIGITS):')
      READ(*,26) NUMCP
 26   FORMAT(BN,I3)
      WRITE(*,27) NUMCP
 27   FORMAT(' ','ENTER *COMPONENT*  *START DATE*',
     &' *PRODUCTION AMOUNT*',/,' ',
     &' ON A SINGLE LINE. (10 ALPHA,3 DIGITS,3 DIGITS):',
     &/,' ','DO IT',I4,' TIMES')
C
      DO 100 I = 1,NUMCP
```

```
         READ(*,102) CPNENT(I),STDATE(I),CPAMT(I)
  102    FORMAT(BN,A10,2I4)
  100 CONTINUE
C
      WRITE(*,103)
  103 FORMAT(' ','**** PROCESSING .....')
C
C CALL SUBROUTINE GETINP TO OPEN AND READ FILES
C
      CALL GETINP
C
C OPEN OUTPUT FILES
C
      OPEN (6,FILE='PRN')
C
C CALL SUB-PROGRAM CAP TO CALCULATE THE CRITICAL PATHS
C
      CALL CPA
C
C CALL SUB-PROGRAMS FOR PRODUCING REPORTS
C
      CALL WCLR (DAY,MONTH,YEAR,PCDAYN,MONDAY,NEG)
      IF (NEG .NE. 0) THEN
         CALL OVERLR (DAY,MONTH,YEAR,NEG)
      ENDIF
C
      CALL CPSR (DAY,MONTH,YEAR)
C
      END
C
C
C
C
      SUBROUTINE GETINP
C
C     ************************************************
C     * THIS ROUTINE OPEN FILES 'WORKFL' & 'CENTREFL' *
C     * IT READS THE DATA FROM THESE FILES AND STORE  *
C     * THE INFORMATION IN COMMON BLOCK AREA /WORK/   *
C     * AND /CENTR/ RESPECTIVELY.                     *
C     ************************************************
C
      COMMON /USER1/ NUMCP,STDATE(50),CPAMT(50)
C
      COMMON /WORK1/ ACTCD(50,20),DURATN(50,20),
     &               SND(50,20),DESTND(50,20),
     &               MAXACT(50),MAXND(50)
      COMMON /WORK2/ CPID(50)
      COMMON /WORK3/ JPRE1(50,20),JPRE2(50,20),
     &               JPRE3(50,20),JNXT1(50,20),
     &               JNXT2(50,20),JNXY3(50,20)
C
      COMMON /CENTR1/ MACTCD(50),MAXCAP(50),MACT
      COMMON /CENTR2/ MCODE(50)
```

```
C
      CHARACTER*1 A,MCODE*4,CPID*10
C
      INTEGER ACTCD,DURATN,SND,DESTND,STDATE,CPAMT
C
C OPEN INPUT FILES
C
      OPEN (1,FILE='WORKFL')
      OPEN (2,FILE='CENTREFL')
C
C READ WORK CENTER FILE AND STORE INFORMATION
C IN COMMON /CENTR/
C
      READ(2,100) MACT
 100  FORMAT(I3)
      DO 200 I = 1,MACT
         READ(2,220) MACTCD(I),MAXCAP(I),A,MCODE(I)
 220     FORMAT(I3,I4,A1,A4)
 200  CONTINUE
C
C READ WORK FILE AND STORE INFORMATION IN COMMON /WORK/
C
      DO 800 I = 1,NUMCP
         READ (1,300) CPID(I),MAXCAP(I),MAXND(I)
 300     FORMAT(A10,2I3)
         DO 700 J = 1,MAXACT(I)
            READ(1,301) ACTCD(I,J),DURATN(I,J),SND(I,J),
     &                  DESTND(I,J)
 301        FORMAT(I3,I4,2I3)
            READ(1,305) JPRE1(I,J),JPRE2(I,J),JPRE3(I,J)
 305        FORMAT(I4,2I3)
            READ(1,307) JNXT1(I,J),JNXT2(I,J),JNXT3(I,J)
 307        FORMAT(I4,2I3)
 700     CONTINUE
 800  CONTINUE
C
      RETURN
      END
C
C
C
C
       SUBROUTINE CPA
C
C      ***********************************************
C      * THIS ROUTINE CALCULATES THE CRITICAL PATH *
C      * FOR ALL COMPONENTS (ICOMP), AND ALL THE   *
C      * "CRITICAL POINTS" IN THE PATH.            *
C      ***********************************************
C
C
       INPUT PARAMETER  : NONE
       OUTPUT PARAMETER : NONE
C
```

```
C
      COMMON /USER1/ NUMCP,STDATE(50),CPAMT(50)
C
      COMMON /WORK1/ ACTCD(50,20),DURATN(50,20),
     &               SND(50,20),DESTND(50,20),
     &               MAXACT(50),MAXND(50)
     &               JPRE3(50,20),JNXT1(50,20),
     &               JNXT2(50,20),JNXY3(50,20)
C
      COMMON /CRITF/ CRIPTS(15,50)
C
      INTEGER NFIN(100)
      INTEGER ACTCD,DURATN,SND,DESTND,STDATE,CPAMT
     &        CRIPTS,NFIN(100),NDUR
C
C INITIALISE WORKING ARRAY
C
      DO 5 I = 1,10
         DO 7 J = 1,10
            CRIPTS(I,J) = 0
 7       CONTINUE
 5    CONTINUE
C
      DO 10 I = 1,100
         NFIN(I) = 0
 100  CONTINUE
C
C COMPUTE CRITICAL PATHS FOR ALL COMPONENTS
C
      DO 800 ICOMP = 1,NUMCP
C
C FIRST TIME IE. NODE 1
C
      DO 111 ID = 1,NUMCP
         IF (CPID(ICOMP) .EQ. CPNENT(ID)) THEN
            CRIPTS(1,ICOMP) = STDATE(ID)
            GOTO 222
         ENDIF
 111  CONTINUE
C
 222  LOOK = 1
      NODE = 2
      LONGST = 0
C
C LOOP FOR ALL DESTINATION NODE FROM 2 TO MAXND
C
      DO 500 M = 2,MAXND(ICOMP)
         NODE = M
         DO 100 I = 1,MAXACT(ICOMP)
C
C        LOOP FOR THAT NODE;
C        IF MATCHES, STORE THE FINISH DAY
C
            IF (DESTND(ICOPM,I) .EQ. NODE) THEN
```

```
               NDUR = DURATN(ICOMP,I)
               NFIN(LOOK) = CRIPTS(NODE-1,ICOMP)
     &                       + NDUR - 1
               LOOK = LOOK + 1
            ENDIF
 100     CONTINUE
C
C COMPARE ALL ACTIVITIES WITH THE SAME DESTINATION
C NODE THAT HAS BEEN LOOKED AT; AND TAKE THE LONGEST
C VALUE.
C
          L = LOOK - 1
          DO 200 K = 1,L
             IF (NFIN(K) .GT. LONGST) THEN
                 LONGST = NFIN(K)
             ENDIF
 200      CONTINUE
C
C         STORE THE LONGEST VALUE
C
          CRIPTS(NODE,ICOMP) = LONGST
C
C         REINITIALISE LOCAL WORKING ARRAYS AND VARIABLES
C
          DO 300 K = 1,L
             NFIN(K) = 0
 300      CONTINUE
          LOOK = 1
          LONGST = 0
C
 500   CONTINUE
 800   CONTINUE
C
       RETURN
       END
C
C
C
C
      SUBROUTINE WCLR (DAY,MONTH,YEAR,PCDAYN,MONDAY,NEG)
C
C     ***********************************************
C     * THIS ROUTINE PRODUCES THE WORK CENTER LOAD    *
C     * REPORT FOR EACH WORK CENTER.                  *
C     ***********************************************
C
      INPUT PARAMETER : DAY,MONTH,YEAR,PCDAYN,NEG
      OUTPUT PARAMETER : NONE
C
C
C
      COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
     &               ISORCE(100),IDEST(100),
     &               IPRE(100,3),INEXT(100,3),IPTR
```

```
      COMMON /STRF2/ ICP(100)
C
      COMMON /EARLF/ IEARL(100)
C
      COMMON /CALF/ AWEEK(50,2),CPNEED(50),MAXWK
C
      COMMON /OVER1/ IFROM(80),ITO(80),IVALUE(80)
      COMMON /OVER2/ ICENTR(80)
C
      COMMON /CENTR1/ MACTCD(50),MAXCAP(50),MACT
      COMMON /CENTR2/ MCODE(50)
C
      INTEGER AWEEK,CPNEED,DAY,MONTH,YEAR,PCDAYN
C
      CHARACTER*1 ICP*10,MCODE*4,ICENTR*4
C
C READ WORK CENTER FILE UNTIL END-OF-FILE
C
      NEG = 0
C
      DO 300 MC = 1,MACT
         CALL INIT
C
C FOR EACH MCODE, PRINT THE WORK CENTER LOAD REPORT.
C HENCE, SEARCH WORK FILE FOR COMPONENTS WITH
C MATCHING MACTCD.
C
      MCAC = MATCD(MC)
      CALL RDWORK(MCAC)
      CALL SORT
      CALL CALCAP
C
C PRINT WCL REPORT HEADING
C
      WRITE(6,303) MONTH,DAY,YEAR
 303  FORMAT('1','ARGO ENGINEERING LIMITED',30X,
     &' DATE :',I2,'/',I2,'/',I2)
       WRITE(6,304) MCODE(MC),MACTCD(MC)
 304   FORMAT('0',/,'0',/,' ',20X,'**** WORK CENTER',
     &' LOAD REPORT ****',/,'0',/,'0','WORK CENTER :',
     &A4,45X,'ACTIVITY :',I3)
      WRITE(6,305)
 305  FORMAT('0',/,' ',80('-'),/,
     &' ','FROM   TO',4X,'CAPACITY NEEDED',4X,
     &'CAPACITY AVAILABLE',4X,' BALANCE',/,' ',80('-'))
C
C PRINT REPORT INFORMATION
C
      DO 700 IWK = 1,MAXWK
         IBAL = MAXCAP(MC) - CPNEED(IWK)
         WRITE(6,306) AWEEK(IWK,1),AWEEK(IWK,2),
     &                CPNEED(IWK),MAXCAP(MC),IBAL
 306     FORMAT(' ',I4,1X,I4,4X,I10,4X,I10,11X,I10)
C
```

```
C CHECK FOR OVERLOAD
C
          IF (IBAL .LT. 0) THEN
             NEG = NEG + 1
             ICENTR(NEG) = MCODE(MC)
             IFROM(NEG) = AWEEK(IWK,1)
             ITO(NEG) = AWEEK(IWK,2)
             IVALUE(NEG) = IBAL
          ENDIF
 700  CONTINUE
C
 300  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE CPSR (DAY,MONTH,YEAR)
C
C     **************************************************
C     * THIS ROUTINE PRODUCES THE COMPONENT PART       *
C     * SCHEDULING REPORT FOR EACH ACTIVITY CODE.      *
C     **************************************************
C
C
C     INPUT PARAMETER  : DAY,MONTH,YEAR
C     OUTPUT PARAMETER : NONE
C
      COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
     &               ISORCE(100),IDEST(100),
     &               IPRE(100,3),INEXT(100,3),IPTR
      COMMON /STRF2/ ICP(100)
C
      COMMON /EARLF/ IEARL(100)
C
      COMMON /CENTR1/ MACTCD(50),MAXCAP(50),MACT
      COMMON /CENTR2/ MCODE(50)
C
      INTEGER DAY,MONTH,YEAR
C
      CHARACTER*1 ICP*10,A,MCODE*4
C
C READ & PROCESS WORK CENTER FILE UNTIL EOF
C
      DO 300 MC = 1,MACT
C
C INITIALISE DATA IN COMMON BLOCK /STRF/
C
         CALL INIT
C
C FOR EACH MACTCD,PRINT THE COMPONENT PART SCHEDULING
C REPORT. HENCE, SEARCH WORK FILE FOR COMPONENTS WITH
```

```
C MATCHING MACTCD,AND STORE INFORMATION IN COMMON
C BLOCK /STRF/
C
         MCAC = MACTCD(MC)
         CALL RDWORK(MCAC)
C
C SORT DATES IN ASCENDING ORDER
C
         CALL SORT
C
C PRINT CPS REPORT WITH THE EARLIEST START-DATE
C PRINT REPORT HEADING
C
         WRITE(6,303) MONTH,DAY,YEAR
 303     FORMAT('1','ARGO ENGINEERING LIMITED',30X,
     &           'DATE :',I2,'/',I2,'/',I2)
         WRITE(6,304) MCODE(MC),MACTCD(MC)
 304     FORMAT('0',/,'0',/,' ',10X,
     &'**** COMPONENT PART SCHEDULING REPORT ****',/,
     &'0',/,'0',/,' ','WORK CENTER :',A4,45X,
     &'ACTIVITY :',I3)
         WRITE(6,305)
 305     FORMAT('0',/,' ',80('-'),/,
     &'PART NO      START    FINISH    DURATION  ',
     &'PRECEDENCE ',46X,'ACTIVITY   ACTIVITY',/,' ',
     &80('-'))
C
C READ # IN ARRAY IEARL AND PRINT THE INFORMATION
C FROM COMMON BLOCK /STRF/ IN THE ORDER OF THE
C NUMBER IN IEARL.
C
      IF (IPTR .NE. 1) THEN
         NPTR = IPTR - 1
         DO 400 K = 1,NPTR
            DO 450 J = 1,NPTR
               IF (IEARL(J) .EQ. K) THEN
                  WRITE(6,306) ICP(J),ISTART(J),
     &            IFIN(J),IDUR(J),(IPRE(J,N),N=1,3),
     &            (INEXT(J,N),N=1,3)
 306              FORMAT(' ',A10,2X,I4,7X,I4,8X,5X,
     &            3I3,3X,3I3)
                  GOTO 400
               ENDIF
 450        CONTINUE
 400     CONTINUE
      ENDIF
 300  CONTINUE
C
      RETURN
      END
C
C
C
C
```

```
      SUBROUTINE OVERLR (DAY,MONTH,YEAR,INEG)
C
C     ************************************************
C     * THIS ROUTINE PRODUCES THE OVERLOAD REPORT    *
C     * (IF ANY).                                    *
C     ************************************************
C
C
C     INPUT PARAMETER  : DAY,MONTH,YEAR,INEG
C     OUTPUT PARAMETER : NONE
C
C
      COMMON /OVER1/ IFROM(80),ITO(80),IVALUE(80)
      COMMON /OVER2/ ICENTR(80)
C
      INTEGER DAY,MONTH,YEAR
C
      CHARACTER*4 ICENTR
C
C CHECK IF THERE IS ANY OVERLOAD REPORT TO BE PRINTED.
C
      IF (INEG .NE. 0) THEN
         WRITE(6,100) MONTH,DAY,YEAR
 100     FORMAT('1','ARGO ENGINEERING LIMITED',30X,
     &   'DATE : ',I2,'/',I2,'/',I2)
         WRITE(6,102)
 102     FORMAT('0',20X,'**** SUMMARY OVERLOAD REPORT',
     &' ****',/,'0',/,'0',80('-'),/,' ',15X,
     &'WORK CENTER        DAY',15X,'OVERLOAD',/,
     &33X'FROM    TO',/,' ',80('-'))
C
         DO 300 I = 1,INEG
            WRITE(6,104) ICENTR(I),IFROM(I),ITO(I),
     &                   IVALUE(I)
 104        FORMAT(' ',20X,A4,8X,I4,1X,8X,I10)
 300     CONTINUE
C
      ENDIF
C
      RETURN
      END
C
C
C
C
      SUBROUTINE RDWORK (MCAC)
C
C     ************************************************
C     * THIS ROUTINE READS THE WORK FILE AND SEARCH  *
C     * FOR COMPONENTS WITH MATCHING ACTIVITY CODE.  *
C     * (MCAC). IT RECORDS ALL THE MATCHING          *
C     * ACTIVITES AND ITS ASSOCIATED DATA INTO       *
C     * COMMON BLOCK /STRF/                          *
C     ************************************************
```

```
C
C
      INPUT PARAMETER  : MCAC
      OUTPUT PARAMETER : NONE
C
C
C MCAC   - CURRENT MACHINE ACTIVITY CODE TO BE PROCESSED
C
      COMMON /USER1/ NUMCP,STDATE(50),CPAMT(50)
C
      COMMON /WORK1/ ACTCD(50,20),DURATN(50,20),
     &               SND(50,20),DESTND(50,20),
     &               MAXACT(50),MAXND(50)
C
      INTEGER ACTCD,DURATN,SND,DESTND,STDATE,CPAMT
C
C FOR EACH COMPONENT, CHECK ALL ITS ACTIVITIES
C FOR MATCHING MACTCD.
C
     DO 300 I = 1,NUMCP
        DO 208 N = 1,MAXACT(I)
           IF (MCAC .EQ. ACTCD(I,N)) THEN
              CALL CRPSTR(I,N)
           ENDIF
 208    CONTINUE
 300  CONTINUE
C
      RETURN
      END
C
C
C
C
       SUBROUTINE CRPSTR (NCOMP,NACT)
C
C      **********************************************
C      * THIS ROUTINE STORES THE INFORMATION        *
C      * REGARDING THE "FOUND" MATCHING ACTIVITIES  *
C      * IN COMMON BLCOK /STRF/.                    *
C      **********************************************
C
C
       INPUT PARAMETER  : NCOMP,NACT
       OUTPUT PARAMETER : NONE
C
C
C      NCOMP  - COMPONENT NUMBER
C      NACT   - ACTIVITY CODE NUMBER
C
      COMMON /WORK1/ ACTCD(50,20),DURATN(50,20),
     &               SND(50,20),DESTND(50,20),
     &               MAXACT(50),MAXND(50)
      COMMON /WORK2/ CPID(50)
      COMMON /WORK3/ JPRE1(50,20),JPRE2(50,20),
     &               JPRE3(50,20),JNXT1(50,20),
     &               JNXT2(50,20),JNXY3(50,20)
C
      COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
     &               ISORCE(100),IDEST(100),
     &               IPRE(100,3),INEXT(100,3),IPTR
      COMMON /STRF2/ ICP(100)
C
      COMMON /CRITF/ CRIPTS(15,50)
C
      INTEGER ACTCD,DURATN,SND,DESTND,STDATE,CPAMT
      CHARACTER*1 ICP*10,CPID*10
C
C FILL INFORMATION IN COMMON BLOCK /STRF/
C
C     IPTR POINTS TO THE FREE LOCATION IN /STRF/
C     IT IS RESET TO 1 EACH TIME IT STARTS
C     PROCESSING A NEW COMPONENT.
C
      ICP(IPTR) = CPID(NCOMP)
      IDUR(IPTR) = DURATN(NCOMP,NACT)
      ISORCE(IPTR) = SND(NCOMP,NACT)
      IDEST(IPTR) = DESTND(NCOMP,NACT)
      IPRE(IPTR,1) = JPRE1(NCOMP,NACT)
      IPRE(IPTR,2) = JPRE2(NCOMP,NACT)
      IPRE(IPTR,3) = JPRE3(NCOMP,NACT)
      INEXT(IPTR,1) = INXT1(NCOMP,NACT)
      INEXT(IPTR,2) = INXT2(NCOMP,NACT)
      INEXT(IPTR,3) = INXT3(NCOMP,NACT)
C
C LOOK UP FOR THE START AND FINISH DAY
C
      ISTART(IPTR) = CRIPTS(ISORCE(IPTR),NCOMP)
      IFIN(IPTR) = CRIPTS(IDEST(IPTR),NCOMP)
      IPTR= IPTR + 1
C
      RETURN
      END
C
C
C
C
      SUBROUTINE INIT
C
C     ****************************************
C     * THIS ROUTINE INITIALISES DATA IN THE *
C     * COMMON BLOCK AREA /STRF/.            *
C     ****************************************
C
C
      COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
     &               ISORCE(100),IDEST(100),
     &               IPRE(100,3),INEXT(100,3),IPTR
      COMMON /STRF2/ ICP(100)
```

```
C
C INITIALISATION
C
     IPTR = 1
C
      DO 100 I = 1,100
         ISTART(I) = 99999
         IFIN(I) = 0
         IDUR(I) = 0
         ISORCE(I) = 0
         IDEST(I) = 0
         DO 110 J = 1,3
            JPRE(I,J) = 0
            INEXT(I,J) = 0
 110     CONTINUE
 100  CONTINUE
C
      RETURN
      END
C
C
C
C
      SUBROUTINE SORT
C
C     ******************************************
C     * THIS ROUTINE SORTS THE START DATES IN  *
C     * ASCENDING ORDER.                       *
C     ******************************************
C
      COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
     &               ISORCE(100),IDEST(100),
     &               IPRE(100,3),INEXT(100,3),IPTR
C
      COMMON /EARLF/ IEARL(100)
C
      INTEGER IWORK(100)
C
C DUPLICATE INFORMATION IN ISTART TO IWORK FOR THE
C PURPOSE OF SORTING OUT THE EARLIEST START DATE
C AND PUT THE EARLIEST NUMBER IN ARRAY IEARL.
C
C DUPLICATE INFORMATION
C
      IF (IPTR .NE. 1) THEN
          NPTR = IPTR - 1
          DO 220 I = 1,NPTR
             IWORK(I) = ISTART(I)
 220      CONTINUE
C
C SORT
C
      DO 120 J = 1,IPTR
         IELST = 99999
         DO 110 N = 1,NPTR
            IF (IWORK(N) .LT. IELST) THEN
               IELST = IWORK(N)
               IE = N
            ENDIF
 110     CONTINUE
         IEARL(IE) = J
         IWORK(IE) = 99999
 120  CONTINUE
      ENDIF
C
      RETURN
      END
C
C
C
C
       SUBROUTINE CALCAP (MONDAY)
C
C      ******************************************
C      * THIS SUBROUTINE CALCULATES THE CAPACITY *
C      * NEEDED FOR EACH ACTIVITY CODE, STARTING *
C      * FROM THE EARLIEST START DATE.           *
C      ******************************************
C
C      INPUT PARAMETER : MONDAY
C      OUTPUT PARAMETER: NONE
C
       COMMON /STRF1/ ISTART(100),IFIN(100),IDUR(100),
      &               ISORCE(100),IDEST(100),IP(100),
      &               IN(100),IPRE(100,3),INEXT(100,3),
      &               IPTR
C
       COMMON /EARLF/ IEARL(100)
       COMMON /CALF/ AWEEK(50,2),CPNEED(50),MAXWK
C
       INTEGER AWEEK,CPNEED,MON,FRI,CWEEK
       INTEGER BAL(50),NSTART(100),NDUR(100)
C
C INITIALIZATION
C
       KCOUNT = 1
       DO 50 I = 1,50
         CPNEED(I) = 0
         BAL(I) = 0
         DO 70 J = 1,2
            AWEEK(I,J) = 0
 70      CONTINUE
 50    CONTINUE
C
C SORT ISTART & IDUR ACCORDING TO THE ORDER IN THE NUMBER
C IN IEARL
C
       NPTR = IPTR - 1
       DO 400 K = 1,NPTR
          DO 450 J = 1,NPTR
             IF (IEARL(J) .EQ. K) THEN
                NSTART(K) = ISTART(J)
                NDUR(K) = IDUR (J)
                GOTO 400
             ENDIF
 450      CONTINUE
 400   CONTINUE
C
C
       MIN = MONDAY
       MAX = NSTART(NPTR)
       MON = MIN
       FRI = MON + 4
C
C DETERMINE MAXIMUM NUMBER OF WEEKS TO PUT INTO ARRAY
C WEEK
C
       NUM = (MAX - MIN) + 1
       MAWWK = NUM/5
       IF (MOD(NUM,5) .NE. 0) THEN
          MAXWK =MAXWK + 1
       ENDIF
C
C CREATE PRODUCTION CALENDER FOR MAXWK
C      DO 100 I = 1,MAXWK
          AWEEK(I,1) = MON
          AWEEK(I,2) = FRI
          MON = FRI + 1
          FRI = MON + 4
C
C COMPUTE CAPACITY NEEDED STARTING WITH THE EARLIEST
C START DATE AND PUT IT INTO ARRAY CPNEED.
C
      DO 900 IWK = 1,MAXWK
         DO 800 I = KCOUNT,NPTR
             IDIFF = AWEEK(IWK,2) - NSTART(I) + 1
             IF (IDIFF .GT. 0) THEN
                IF (NDUR(I) .LE. IDIFF) THEN
                    CPNEED(IWK) = CPNEED(IWK)+NDUR(I)
                ELSE
                    CPNEED(IWK) = CPNEED(IWK)+IDIFF
                    IREM = NDUR(I) - IDIFF
                    BAL(IWK) = IREM + 1
                ENDIF
             ELSE
C
C         DO THE BALANCES
C
             KCOUNT = I
             CWEEK = IWK
             NWK = IWK + 1
             DO 150 K = 1,CWEEK
```

```
                    IF (BAL(K) .NE, 0) THEN
                       IF (BAL(K) .LE. 5) THEN
                          CPNEED(NWK) = CPNEED(NWK)+BAL(K)
                          BAL(K) = 0
                       ELSE
                          NREM = BAL(K) - 5
                          BAL(K) = NREM
                          CPNEED(NWK) = CPNEED(NWK) + 5
                       ENDIF
                    ENDIF
  150            CONTINUE
                 GOTO 900
                 ENDIF
  800         CONTINUE
  900   CONTINUE
C
        RETURN
        END
```